Department of Defense

High Performance Computing Modernization Program

Science-Based Modeling and Simulation on DoD High Performance Computers

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Deputy Director

http://www.hpcmo.hpc.mil

Presentation Outline

- The Program
- Allocation of Program Resources
- Examples of Science-Based Modeling and Simulation
  - Materials modeling: sonar, non-linear optical, and ceramic armor materials
  - Aircraft modeling: computational fluid dynamics of aircraft and stores; structural mechanics modeling of fatigue and corrosion of aircraft parts

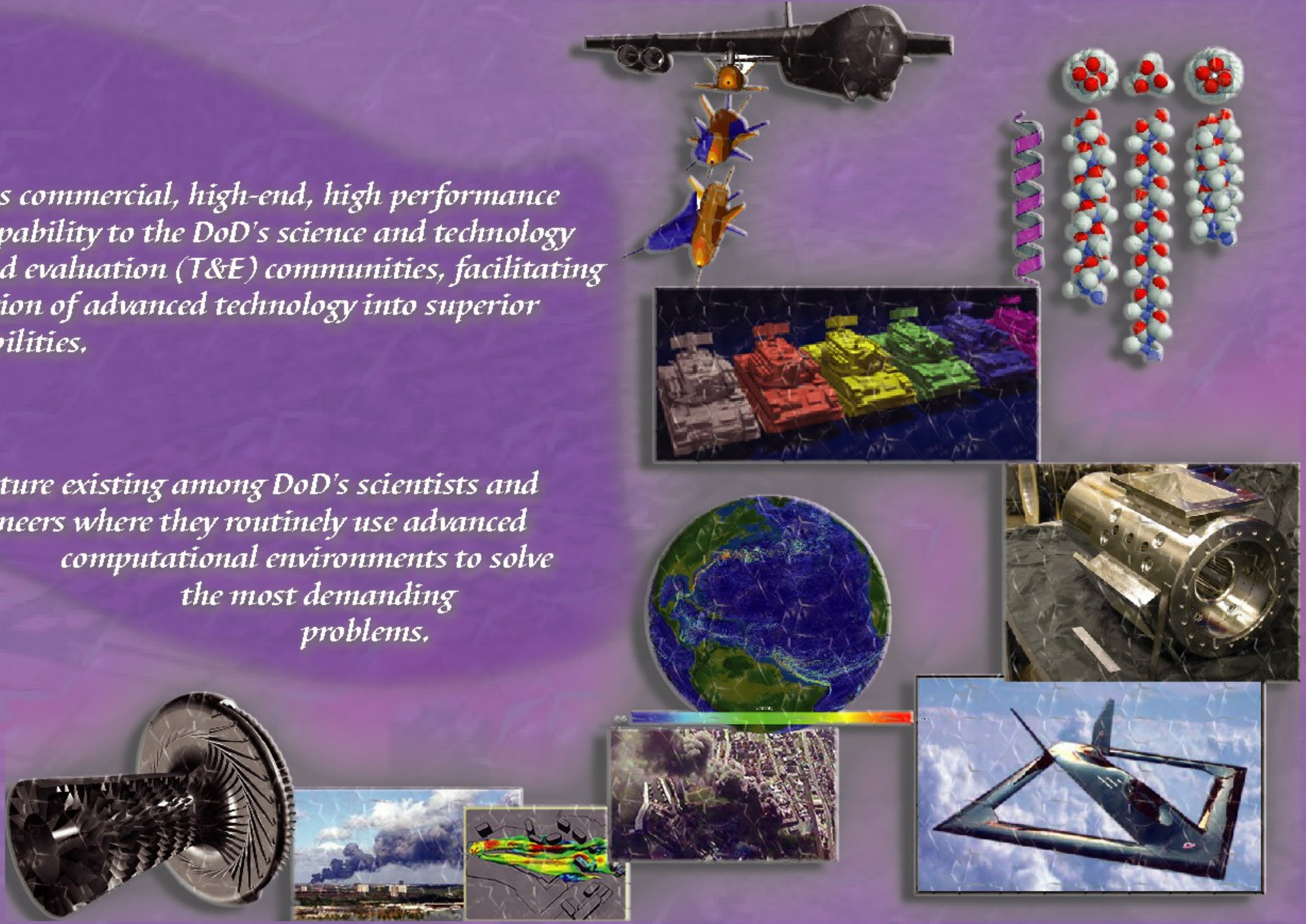
HPC Modernization Program

Mission

Deliver world-class commercial, high-end, high performance computational capability to the DoD's science and technology (S&T) and test and evaluation (T&E) communities, facilitating the rapid application of advanced technology into superior warfighting capabilities.

Vision

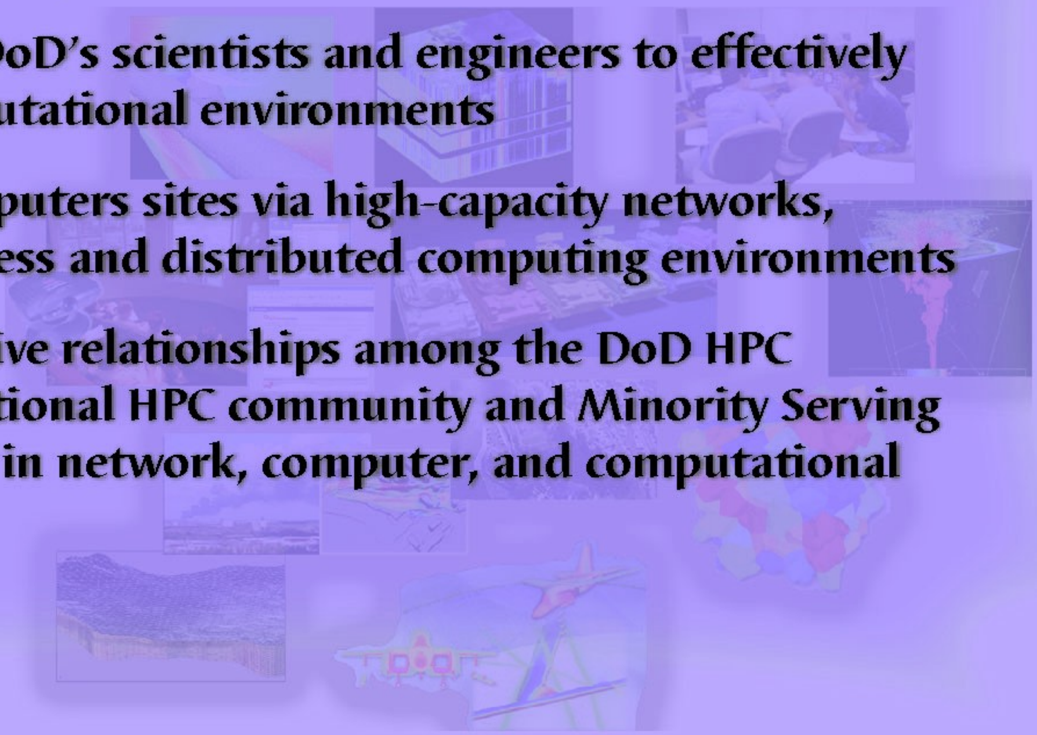
A pervasive culture existing among DoD's scientists and engineers where they routinely use advanced computational environments to solve the most demanding problems.



Tools for Discovery

HPC Modernization Program Goals

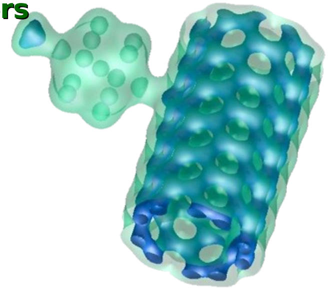
- Provide the best commercially available high-end HPC capability
- Provide high performance computing environments and software applications that enables critical DoD research, development and test problems to be solved
- Educate and train DoD's scientists and engineers to effectively use advanced computational environments
- Link users and computers sites via high-capacity networks, facilitating user access and distributed computing environments
- Promote collaborative relationships among the DoD HPC community, the National HPC community and Minority Serving Institutions (MSIs) in network, computer, and computational science



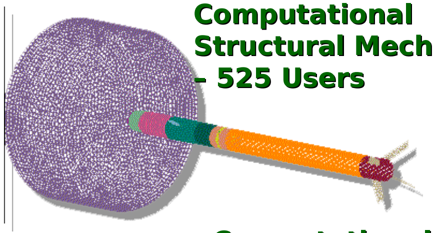
Current User Base and Requirements

- 613 projects and 4,920 users at approximately 178 sites
- Requirements categorized in 10 Computational Technology Areas (CTA)
- FY 2006 non-real-time requirements of 282 Habu-equiv

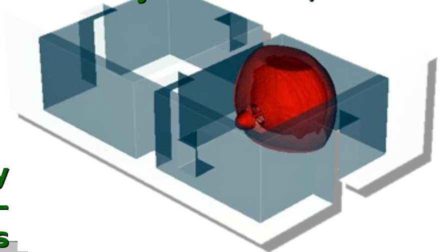
Electronics, Networking, and Systems/C4I – 34 Users



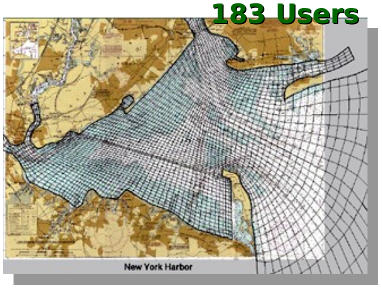
Computational Structural Mechanics – 525 Users



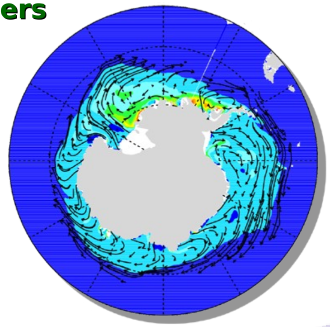
Computational Fluid Dynamics – 1,227 Users



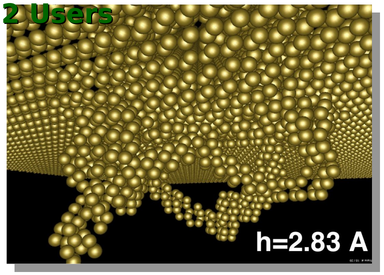
Environmental Quality Modeling & Simulation – 183 Users


New York Harbor

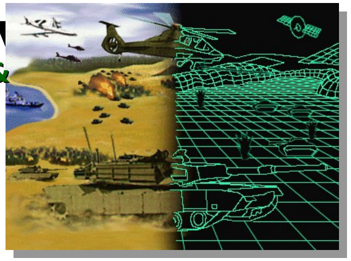
Climate/Weather/Ocean Modeling & Simulation – 233 Users



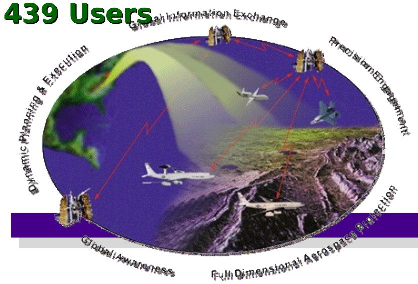
Computational Chemistry, Biology & Materials Science – 332 Users



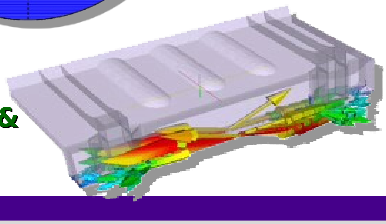
Forces Modeling & Simulation/C4I – 916 Users



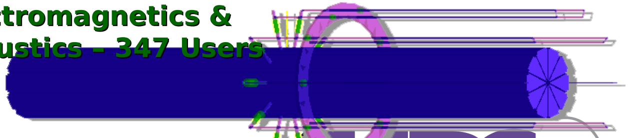
Signal/Image Processing – 439 Users


Global Information Exchange
Precision Engagement
Force Protection
Full Dimensional Aerospace Protection
Global Awareness
Dynamic Planning & Execution

Integrated Modeling & Test Environments – 617 Users



Computational Electromagnetics & Acoustics – 347 Users



67 users are self characterized as "other"

HPC Modernization Program

Air Force HPC Centers/Projects

ASC MSRC
MHPCC ADC
AEDC/AFSEO, AFRL/IF, AFWA, SIMAF, & MHPCC DHPIs
1,227 Users/35 Locations
22 DREN Sites
9 Challenge Projects
2 Institutes/1 Portfolio
3 CTA Leaders/1 Porfolio Leader

Army HPC Centers/Projects

ARL & ERDC MSRCs
AHPCRC & SMDC ADCs
ATC, RTTC, & WSMR DHPIs
1,419 Users/25 Locations
37 DREN Sites
14 Challenge Projects
2 Institutes/3 Portfolios
6 CTA Leaders/3 Porfolio Leaders

Navy HPC Centers/Projects

NAVO MSRC
FNMOC, SSCSD, NAWCAD, NSWCCD, NUWC, & WSMR DHPIs
1,659 Users/24 Locations
23 DREN Sites
11 Challenge Projects
1 Institute/2 Portfolios
1 CTA Leader/2 Porfolio Leaders

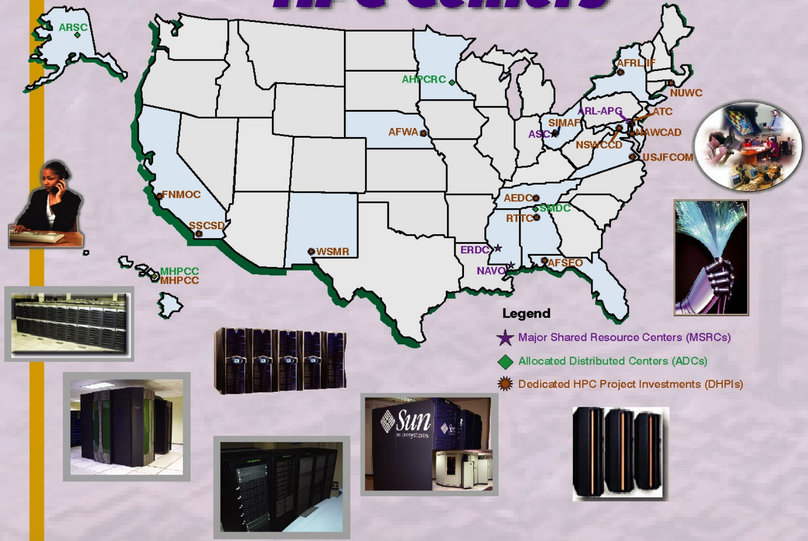
Defense Agencies

DARPA, DTRA, JNIC, JFCOM, JWARS, MDA, & OTE
620 Users/4 Locations
13 DREN Sites
2 Challenge Projects

Other

ARSC ADC

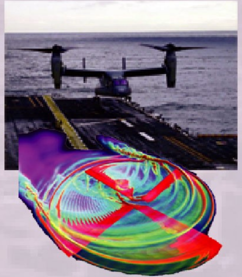
HPC Centers

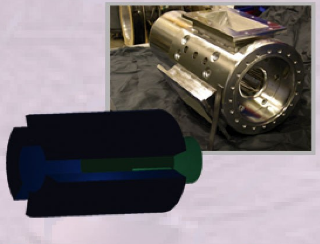


ARSC
AHPCRC
AFWA
AFRL/IF
NUWC
ARL-APG
ATC
SIMAF
ASC
NAWCAD
NSWCCD
USJFCOM
FNMOC
SSCSD
WSMR
AEDC
SMDC
RTTC
ERDC
NAVO
AFSEO
MHPCC
MHPCC
Legend
Major Shared Resource Centers (MSRCs)
Allocated Distributed Centers (ADCs)
Dedicated HPC Project Investments (DHPIs)
Sun
microsystems

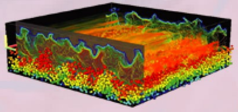
Resource Mgmt

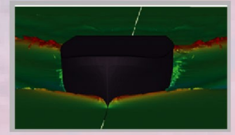
DoD Challenge Projects



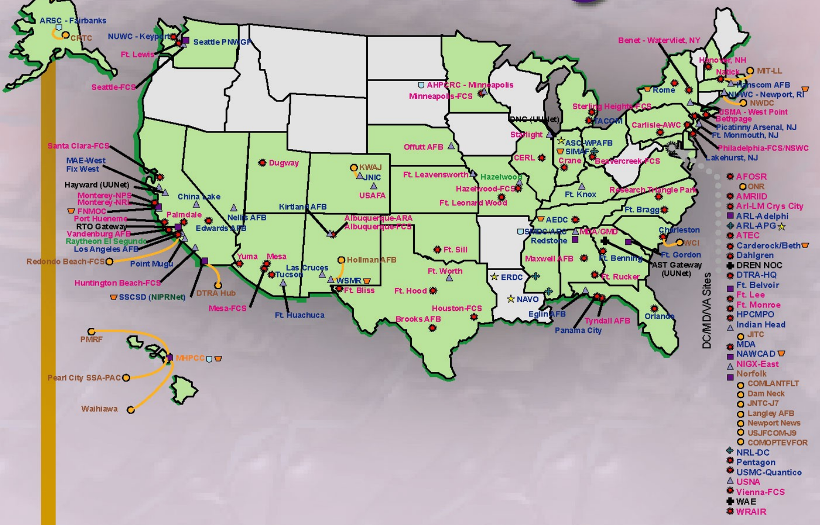


Requirements & Allocations





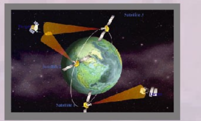
Networking



ARSC - Fairbanks
CRTC
NUWC - Keyport
Seattle PNWGP
Ft. Lewis
Seattle-FCS
Santa Clara-FCS
MAE-West
Fix West
Hayward (UUNet)
Monterey-NPS
Monterey-NRL
FNMOC
Port Hueneme
RTO Gateway
Vandenburg AFB
Raytheon El Segundo
Los Angeles AFB
Redondo Beach-FCS
Point Mugu
Huntington Beach-FCS
SSCSD (NIPRNet)
DTRA Hub
Mesa-FCS
Ft. Huachuca
China Lake
Palmdale
Edwards AFB
Nellis AFB
Dugway
Yuma
Mesa
Tucson
Las Cruces
WSMR
Ft. Bliss
Kirtland AFB
Albuquerque-ARA
Albuquerque-FCS
Hollman AFB
KWAJ
JNIC
USAFA
PMRF
MHPCC
Pearl City SSA-PAC
Waihiawa
AHPCRC - Minneapolis
Minneapolis-FCS
Offutt AFB
Ft. Leavensworth
Hazelwood
Hazelwood-FCS
Ft. Leonard Wood
Ft. Sill
Ft. Worth
Ft. Hood
Houston-FCS
Brooks AFB
ERDC
NAVO
DNC (UUNet)
Starlight
CERL
Crane
ASC-WPAFB
SIMAF
Beavercreek-FCS
Sterling Heights-FCS
TACOM
Ft. Knox
AEDC
SMDC/ARC
Redstone
MDA/GMD
Maxwell AFB
Ft. Benning
Ft. Rucker
Eglin AFB
Panama City
Tyndall AFB
Orlando
Ft. Gordon
AST Gateway (UUNet)
Charleston
WCI
Ft. Bragg
Research Triangle Park
Carlisle-AWC
Rome
Benet - Watervliet, NY
Hanover, NH
Natick
MIT-LL
Hanscom AFB
NUWC - Newport, RI
NWDC
USMA - West Point
Bethpage
Picatinny Arsenal, NJ
Ft. Monmouth, NJ
Philadelphia-FCS/NSWC
Lakehurst, NJ
DC/MD/VA Sites
AFOSR
ONR
AMRIID
Arl-LM Crys City
ARL-Adelphi
ARL-APG
ATEC
Carderock/Beth
Dahlgren
DREN NOC
DTRA-HQ
Ft. Belvoir
Ft. Lee
Ft. Monroe
HPCMPO
Indian Head
JITC
MDA
NAWCAD
NIGX-East
Norfolk
COMLANTFLT
Dam Neck
JNTC-J7
Langley AFB
Newport News
USJFCOM-J9
COMOPTEVFOR
NRL-DC
Pentagon
USMC-Quantico
USNA
Vienna-FCS
WAE
WRAIR

Software Applications Support

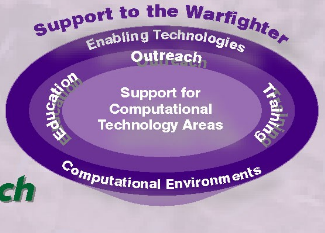
HSAIs/Portfolios



Satellite 1
Satellite 2
Satellite 3

SPI

PET

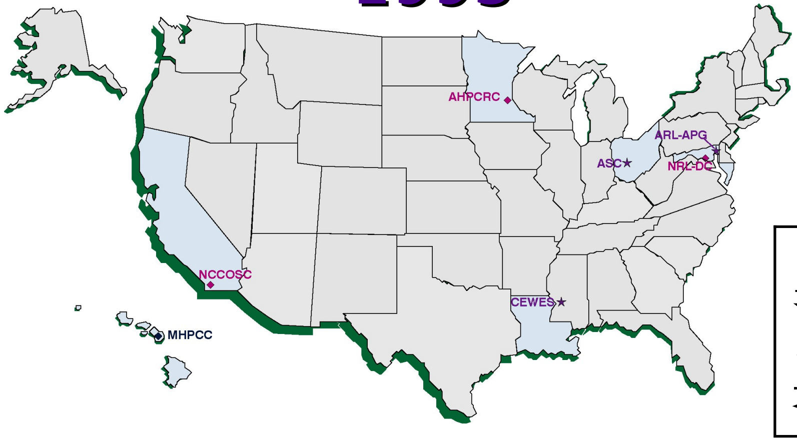


Support to the Warfighter
Enabling Technologies
Outreach
Education
Training
Support for Computational Technology Areas
Computational Environments

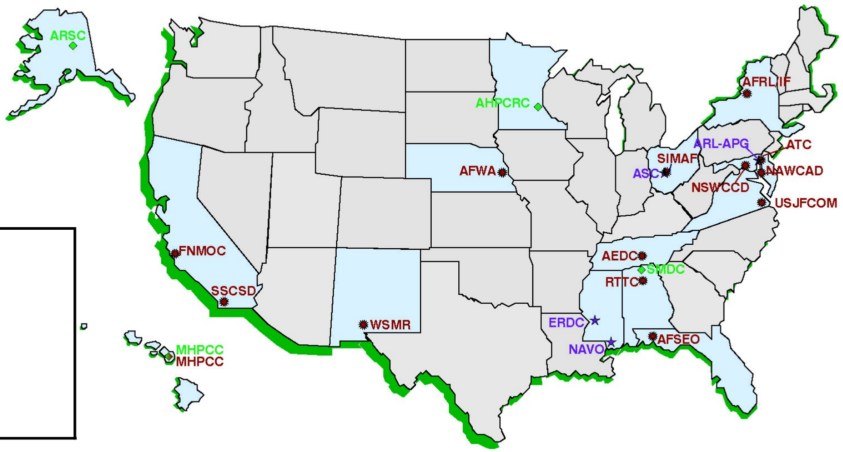
Education Outreach

HPCMP Resources

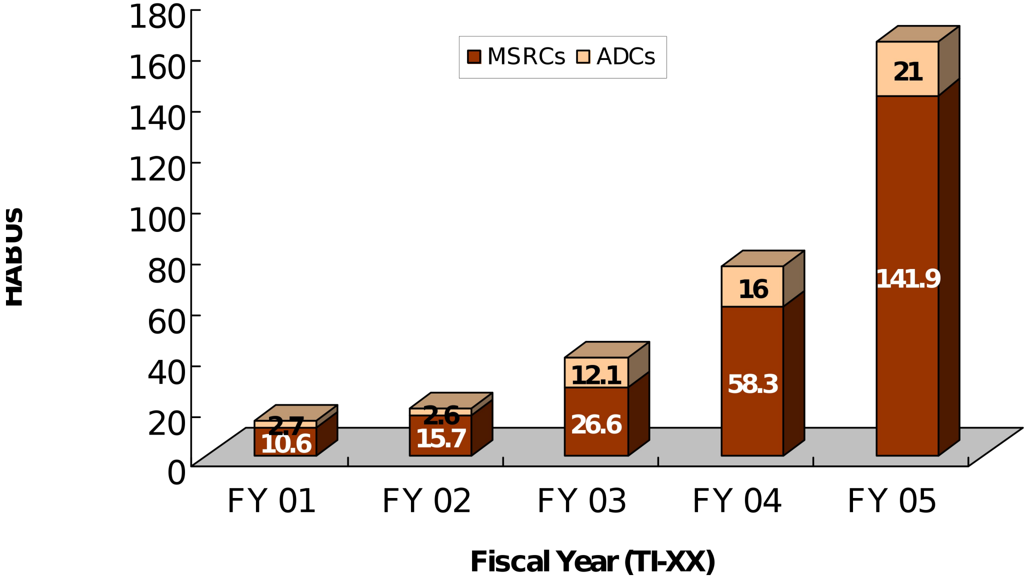
1993


AHPCRC
ARL-APG
ASC
NRL-DC
NCCOSC
CEWES
MHPCC

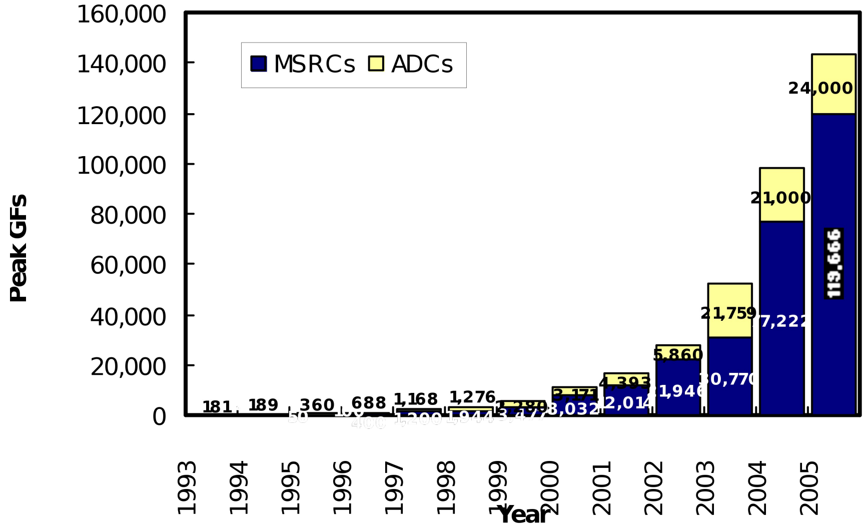
2005


ARSC
AHPCRC
AFRL/IF
ARL-APG
ATC
SIMAF
NAWCAD
AFWA
ASC
NSWCCD
USJFCOM
FNMOC
AEDC
SMDC
RTTC
SSCSD
WSMR
ERDC
AFSEO
NAVO
MHPCC
MHPCC

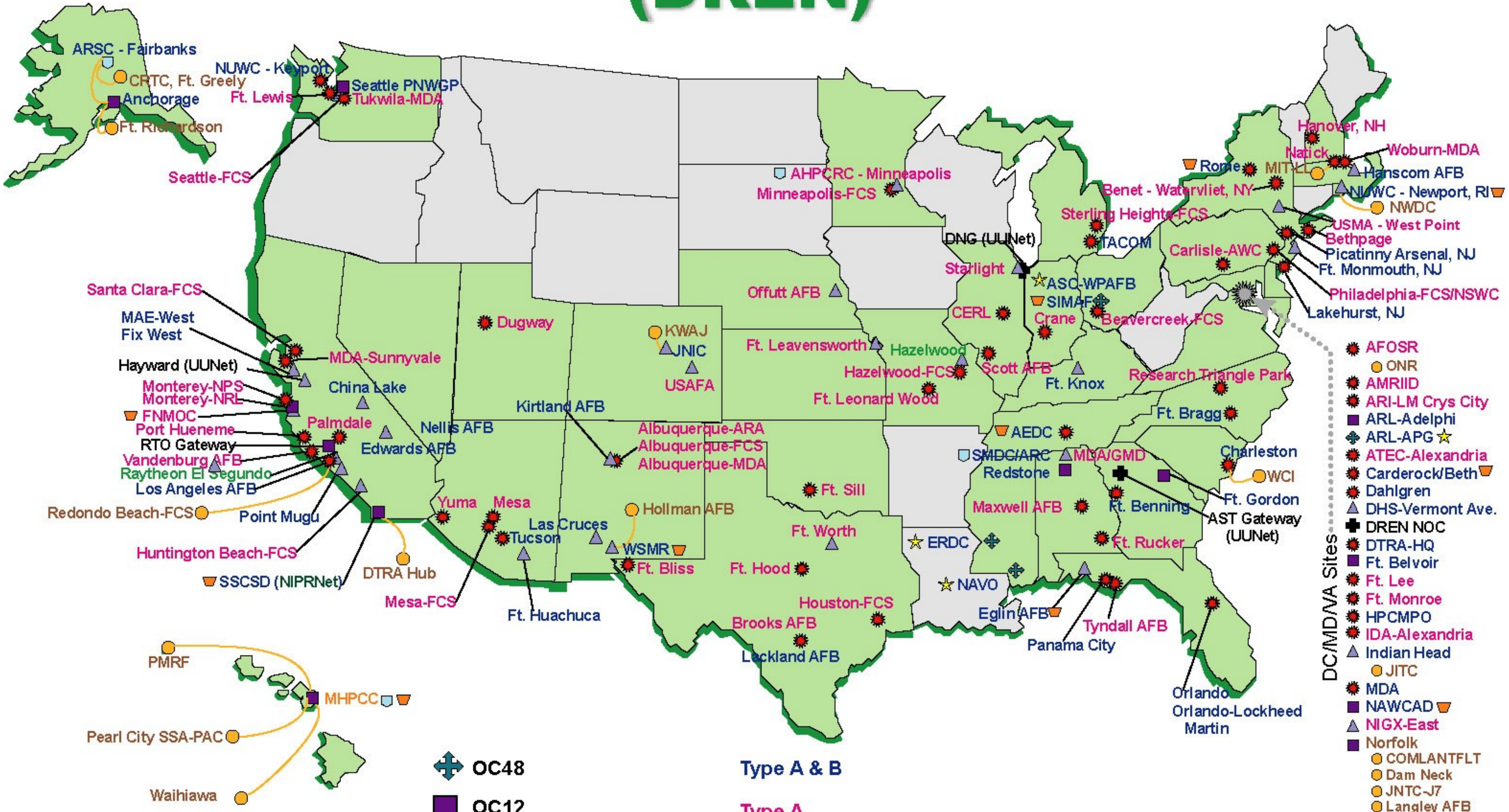
Legend
- ★ **MSRCs**
- ◆ **ADCs**
- ✹ **DHPIs**



Total HPCMP End-of-Year Computational Capabilities



Defense Research & Engineering Network (DREN)


ARSC - Fairbanks
CRTC, Ft. Greely
Anchorage
Ft. Richardson
NUWC - Keyport
Ft. Lewis
Seattle PNWGP
Tukwila-MDA
Seattle-FCS
AHPCRC - Minneapolis
Minneapolis-FCS
DNG (UUNet)
Starlight
ASC-WPAFB
SIMAF
Crane
Beavercreek-FCS
Sterling Heights-FCS
TACOM
Rome
MIT-LL
Hanover, NH
Natick
Woburn-MDA
Hanscom AFB
NUWC - Newport, RI
NWDC
Benet - Watervliet, NY
USMA - West Point
Bethpage
Picatinny Arsenal, NJ
Ft. Monmouth, NJ
Carlisle-AWC
Philadelphia-FCS/NSWC
Lakehurst, NJ
Santa Clara-FCS
MAE-West
Fix West
Hayward (UUNet)
MDA-Sunnyvale
Monterey-NPS
Monterey-NRL
FNMOC
Port Hueneme
RTO Gateway
Vandenburg AFB
Raytheon El Segundo
Los Angeles AFB
Redondo Beach-FCS
Point Mugu
Huntington Beach-FCS
SSCSD (NIPRNet)
DTRA Hub
Mesa-FCS
China Lake
Palmdale
Edwards AFB
Nellis AFB
Dugway
KWAJ
JNIC
USAFA
Kirtland AFB
Albuquerque-ARA
Albuquerque-FCS
Albuquerque-MDA
Yuma
Mesa
Tucson
Las Cruces
Hollman AFB
WSMR
Ft. Bliss
Ft. Huachuca
Offutt AFB
Ft. Leavensworth
Hazelwood
Hazelwood-FCS
Ft. Leonard Wood
CERL
Scott AFB
Ft. Knox
Research Triangle Park
Ft. Bragg
AEDC
SMDC/ARC
Redstone
MDA/GMD
Charleston
WCI
Ft. Gordon
AST Gateway
(UUNet)
Ft. Benning
Maxwell AFB
Ft. Rucker
Ft. Sill
Ft. Worth
Ft. Hood
Houston-FCS
Brooks AFB
Lackland AFB
ERDC
NAVO
Eglin AFB
Panama City
Tyndall AFB
Orlando
Orlando-Lockheed
Martin
PMRF
MHPCC
Pearl City SSA-PAC
Waihiawa

DC/MD/VA Sites

- AFOSR
  - ONR
- AMRIID
- ARI-LM Crys City
- ARL-Adelphi
- ARL-APG
- ATEC-Alexandria
- Carderock/Beth
- Dahlgren
- DHS-Vermont Ave.
- DREN NOC
- DTRA-HQ
- Ft. Belvoir
- Ft. Lee
- Ft. Monroe
- HPCMPO
- IDA-Alexandria
- Indian Head
  - JITC
- MDA
- NAWCAD
- NIGX-East
- Norfolk
  - COMLANTFLT
  - Dam Neck
  - JNTC-J7
  - Langley AFB
  - Newport News
  - USJFCOM-J9
  - COMOPTEVFOR
- NRL-DC
- Pentagon
- USMC-Quantico
- USNA
- Vienna-FCS
- WAE
- WMEBL-Alexandria
- WRAIR

✥ OC48
■ OC12
△ OC3
✹ DS3
✚ DCN and Transit Service
● Tail Connection

Type A & B
Type A
Type B
Tail Site

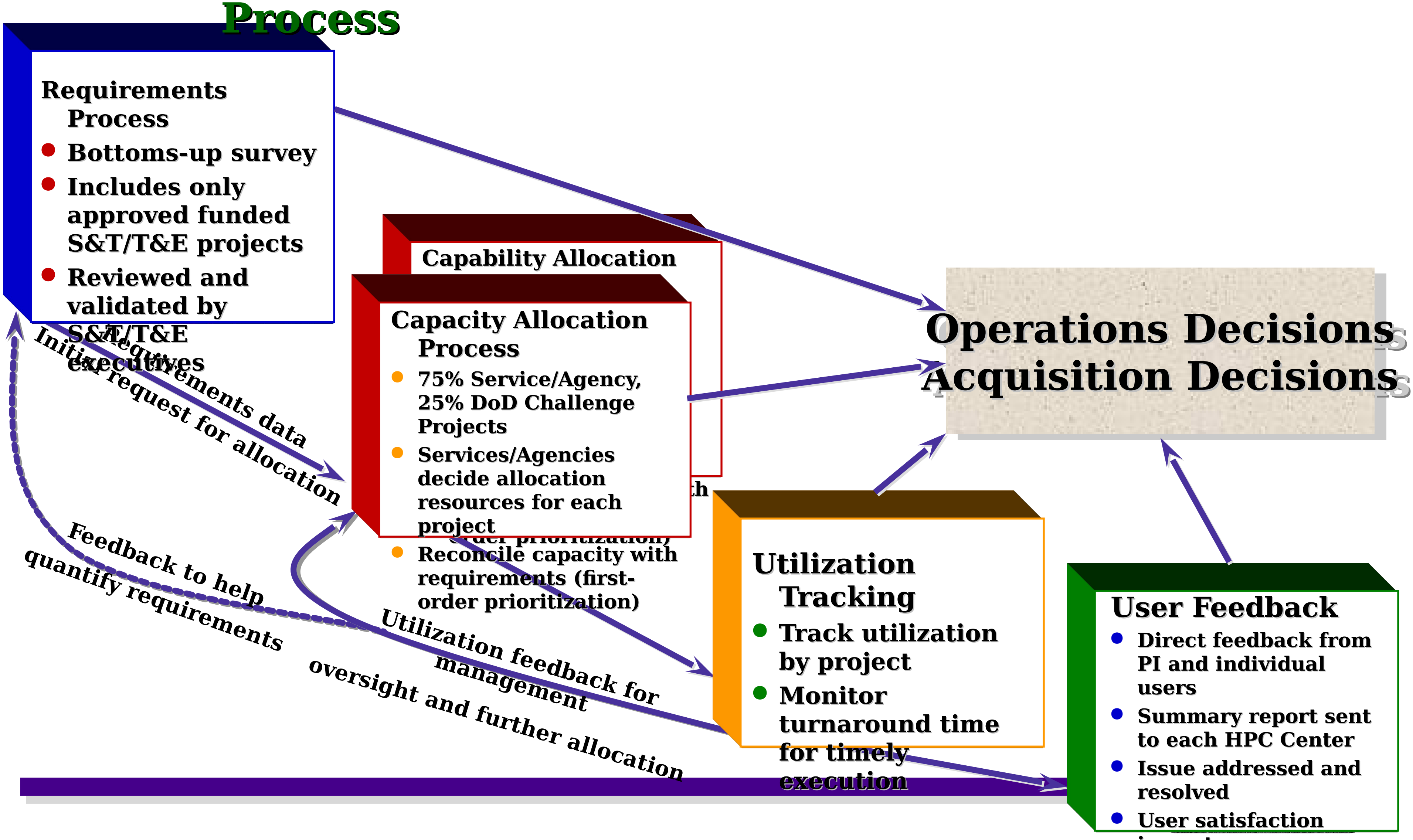
☆ MSRC
⬠ ADC
▽ DHPI

Total number of sites
131

Updated: August 2005

Resource Management

— Integrated Requirements/Allocation/Utilization Process



Requirements Process
- Bottoms-up survey
- Includes only approved funded S&T/T&E projects
- Reviewed and validated by S&T/T&E executives

Initial requirements data

Initial request for allocation

Capability Allocation

Capacity Allocation Process
- 75% Service/Agency, 25% DoD Challenge Projects
- Services/Agencies decide allocation resources for each project
- Reconcile capacity with requirements (first-order prioritization)

Operations Decisions
Acquisition Decisions

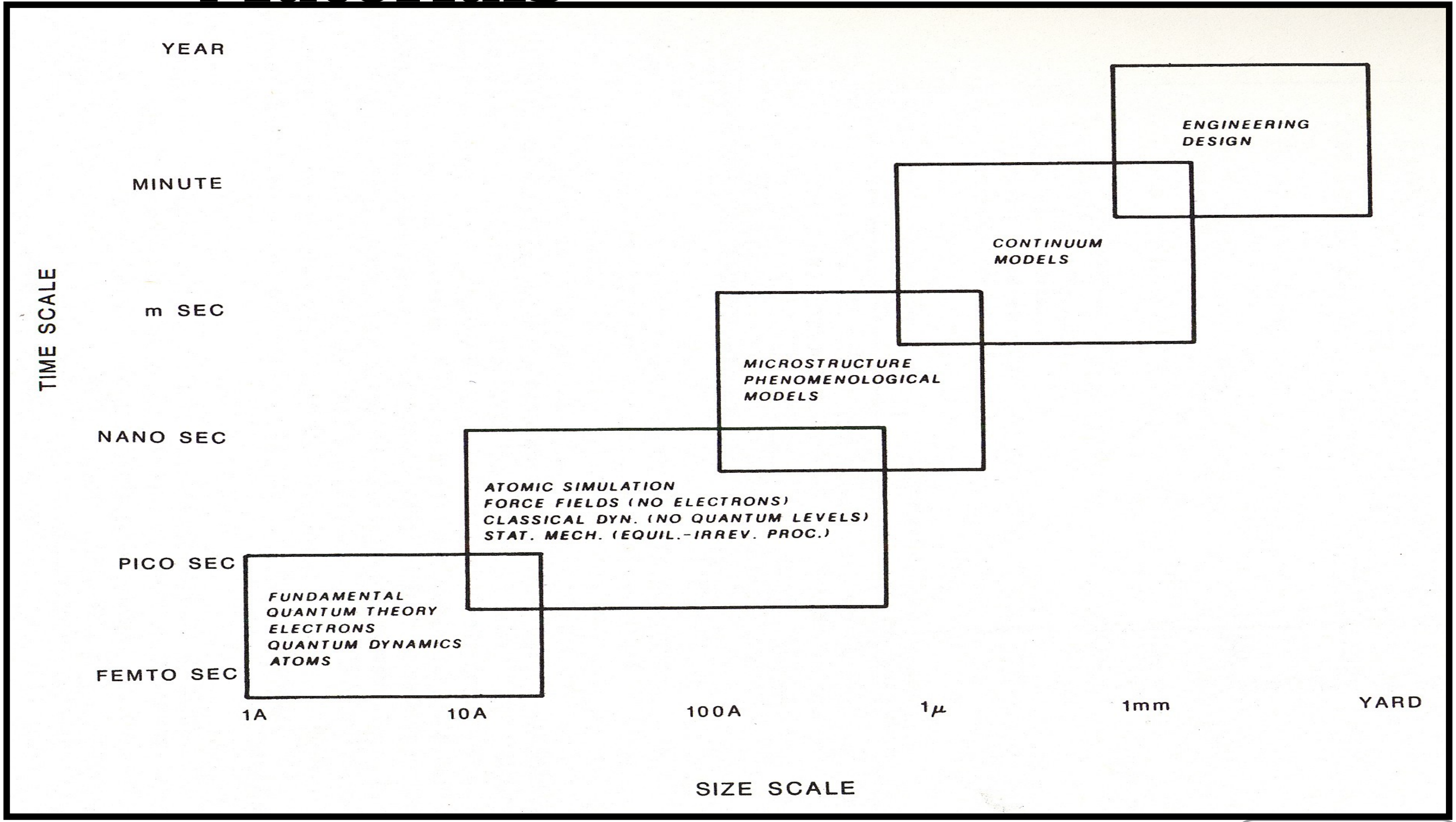
Utilization Tracking
- Track utilization by project
- Monitor turnaround time for timely execution

User Feedback
- Direct feedback from PI and individual users
- Summary report sent to each HPC Center
- Issue addressed and resolved
- User satisfaction

Feedback to help quantify requirements

Utilization feedback for management oversight and further allocation

Towards the Design of Molecular Materials

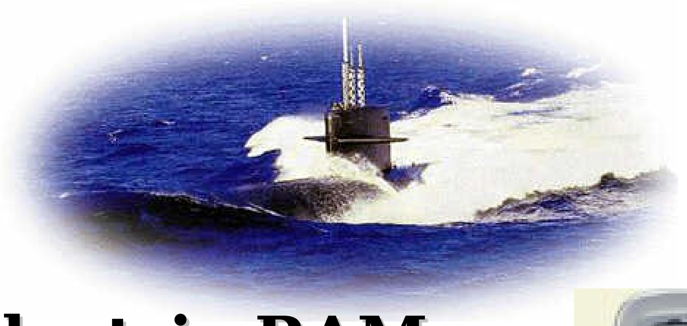

YEAR
MINUTE
m SEC
NANO SEC
PICO SEC
FEMTO SEC
TIME SCALE
ENGINEERING DESIGN
CONTINUUM MODELS
MICROSTRUCTURE PHENOMENOLOGICAL MODELS
ATOMIC SIMULATION
FORCE FIELDS (NO ELECTRONS)
CLASSICAL DYN. (NO QUANTUM LEVELS)
STAT. MECH. (EQUIL.-IRREV. PROC.)
FUNDAMENTAL
QUANTUM THEORY
ELECTRONS
QUANTUM DYNAMICS
ATOMS
1A
10A
100A
1μ
1mm
YARD
SIZE SCALE

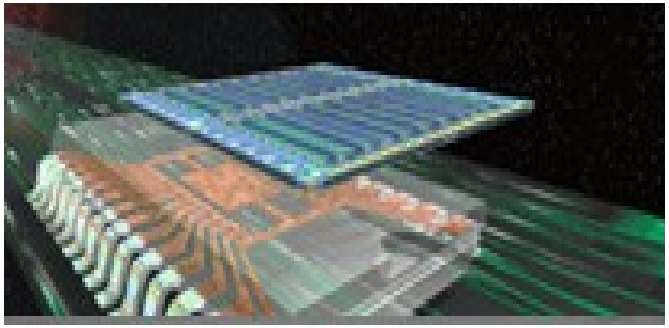
Cocke, '86

Complex Oxide Materials (Andrew Rappe, University of Pennsylvania)

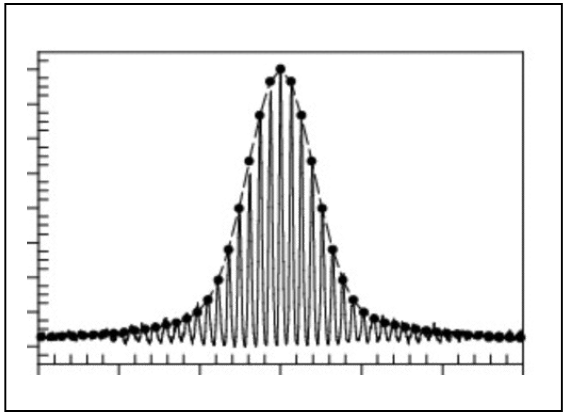
Applications

- Piezoelectrics for SONAR and medical ultrasound



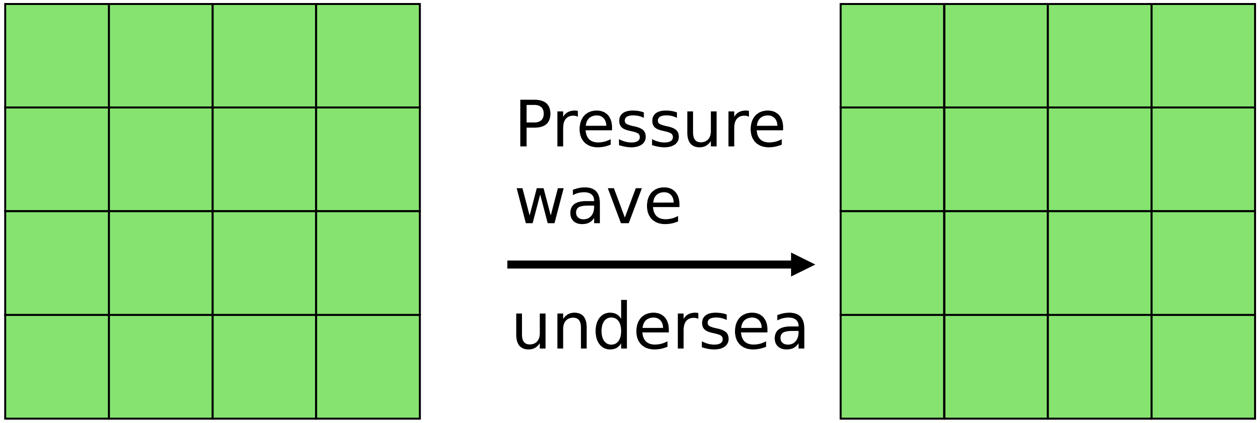


- Ferroelectric RAM for nonvolatile storage; not vulnerable to EMP
- Dielectric resonators for cell-phone communication



- Generating Terahertz frequency light (THz) for detecting improvised explosive devices (IEDs)

How does SONAR work?



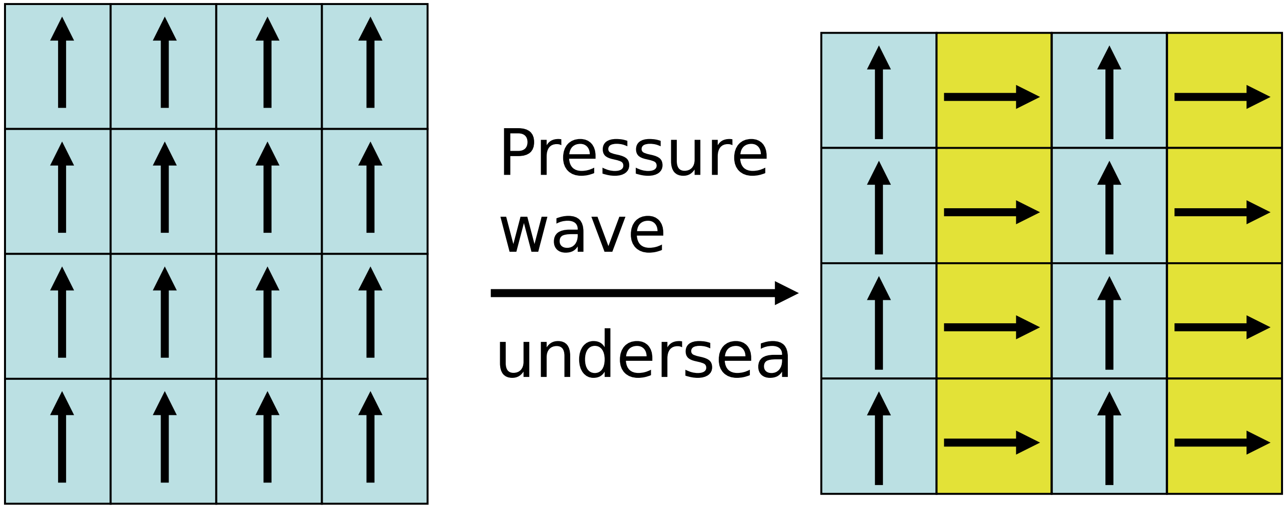
Pressure wave

undersea

Stable structure (cubic)

No change

SONAR has no effect. Not useful as a detector material.



Pressure wave

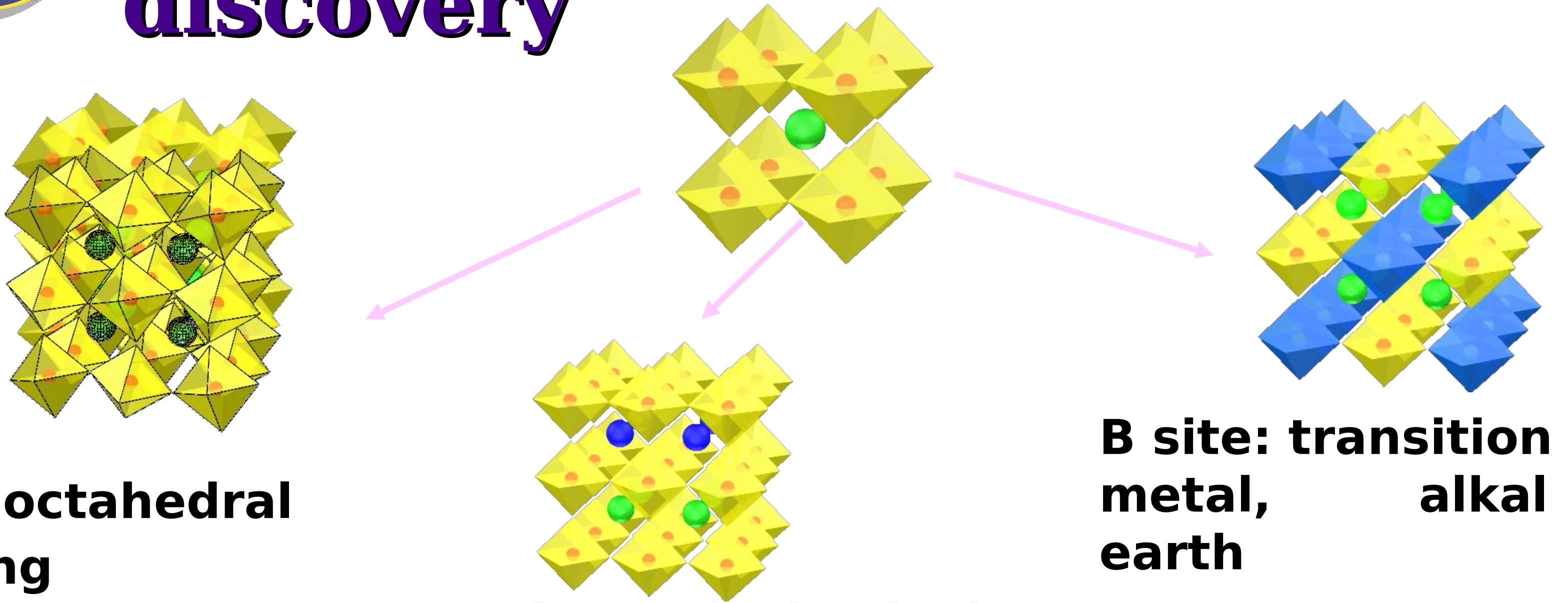
undersea

Single-domain (rectangles)

Multi-domain (cubic)

Pressure easily changes material shape. Great SONAR detector!

ABO_3 palette for materials discovery



BO_6 octahedral tilting

A and B cation motion

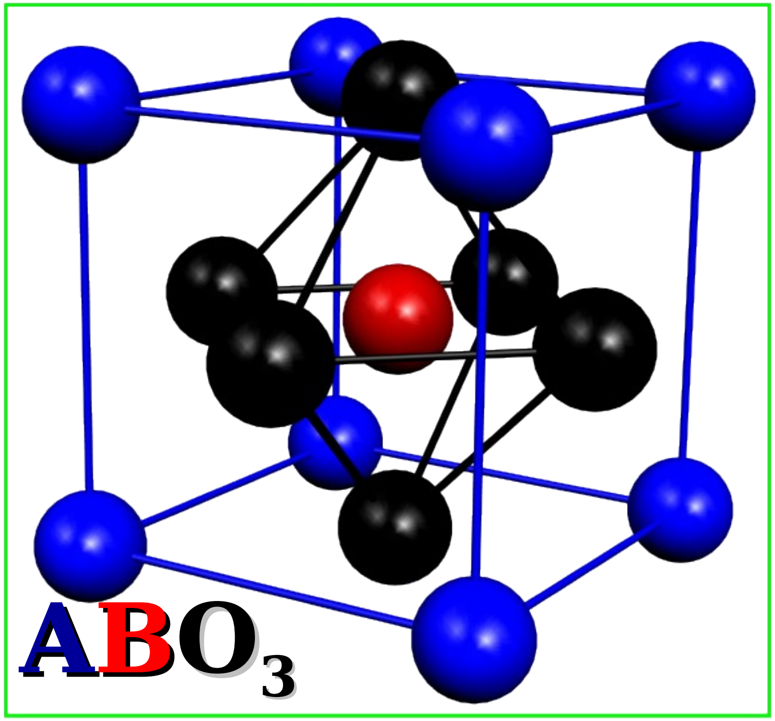
A site: alkali, alkaline earth, rare earth, main group

B site: transition metal, alkaline earth

- **Variety:** Nearly any element for A and B, solid solutions
- **Frustration:** A-O and B-O bond lengths, charges, spins
- **Order/disorder:** Partial ordering, varied correlation length

Ferroelectric Perovskites (ABO_3)

- **Spontaneous polarization,** $\vec{P}$
  - **Cation off-centering forms an electric dipole within unit cell**
- **Polarization can be flipped by applying an external field**
- **Collective phenomenon**
- **How does behavior change when one dimension approaches**



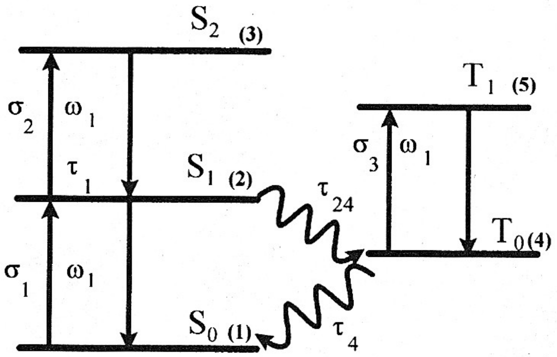
Recent Accomplishments

- Understand and enhance SONAR material response
- Discover new environmentally-friendly materials (replace Pb with Ag!)
- Computational materials design of nonvolatile RAM materials
- Ultrathin NVRAM memory devices

Nonlinear Optical Absorbing Materials (Ruth Pachter, Air Force Research Lab)

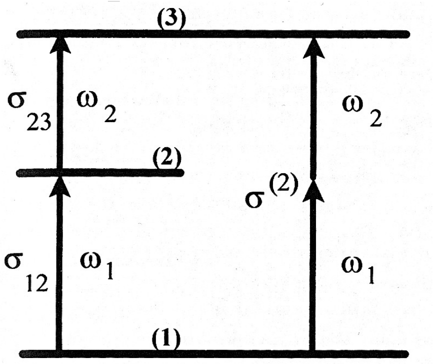
- **Objective:** accurate, reliable, and efficient prediction of structures and spectra for the design of RSA and TPA materials
- **RSA Materials**
  - Porphyrins, phthalocyanines
- **TPA Materials**
  - (D-p-A) stilbenes, fluorene-based

RSA (reverse saturable



S_2 (3)
T_1 (5)
σ_2
ω_1
τ_1
S_1 (2)
τ_{24}
σ_3
ω_1
T_0 (4)
σ_1
ω_1
S_0 (1)
τ_4

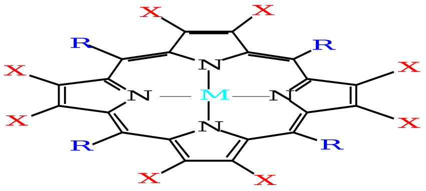
TPA (two-photon



(3)
σ_{23}
ω_2
ω_2
(2)
$\sigma^{(2)}$
σ_{12}
ω_1
ω_1
(1)

Accurate, Reliable, and Efficient Approach

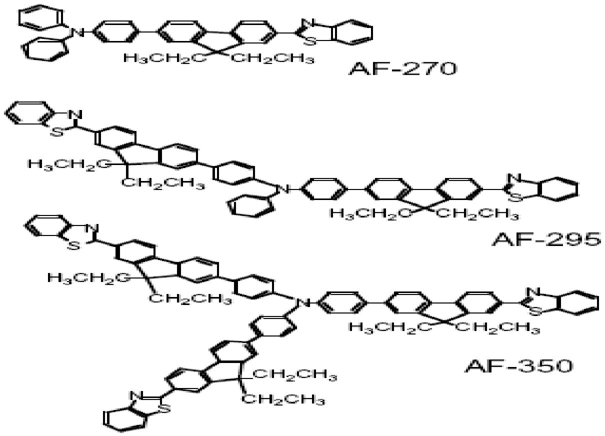
- **Density functional theory:** $O(N^3)$
    - Improvements to Hartree-Fock: MP2-4, CIS/CISD, CCSD(T)…$O(N^5\text{-}N^7)$
- **DFT validation:** structures of model compounds
    - Pyran, C_{20}
    - Meso-alkynyl porphyrins
    - Phthalocyanines
- **Linear response TDDFT:** excitation energies/cross sections
    - Improved (x-c) functionals
- **TDDFT validation:** spectra of



	M	X	R
PH_2	H2	H	H
ZnP	Zn	H	H
$TPPH_2$	Zn	H	phenyl
ZnTPP	Zn	H	phenyl
$ZnTPPX_8$	Zn	F, Cl, Br	phenyl

- Good agreement with experimental trends
- Structural effects discerned
- Ionization potentials estimated

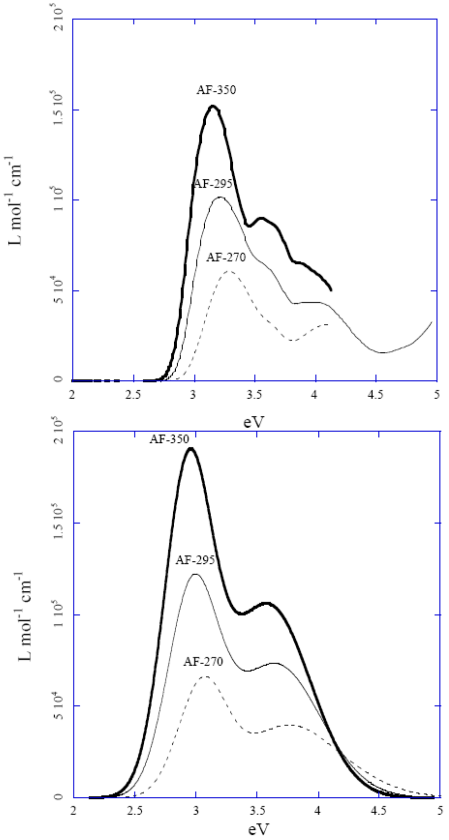
Example: Ground-state Spectra


H3CH2C
CH2CH3
N
S

AF-270

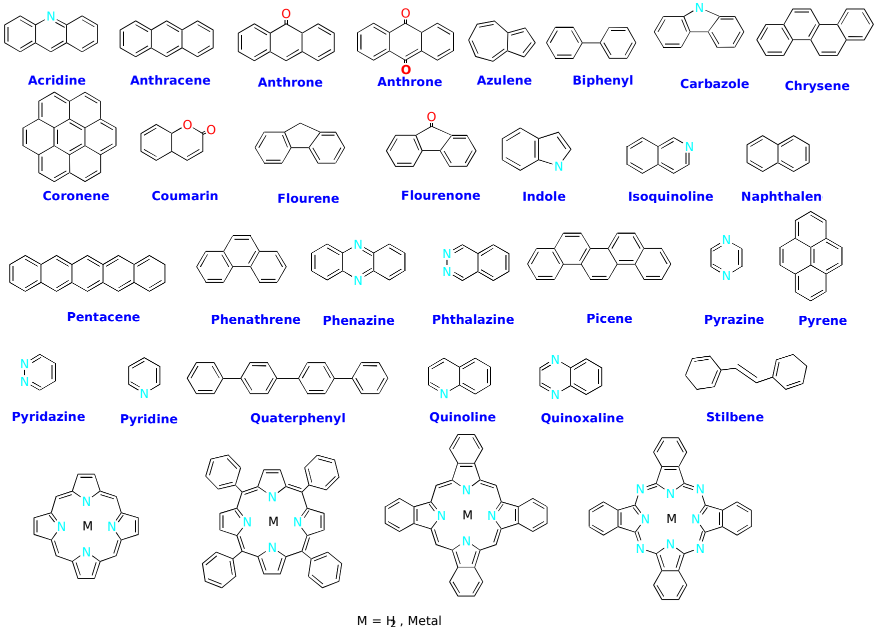
AF-295

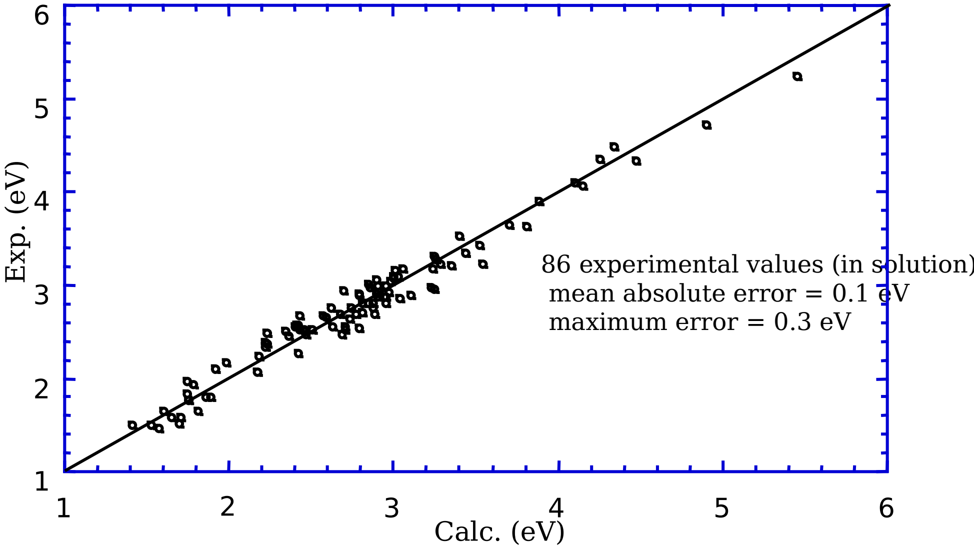
AF-350



Experimental (top) and calculated (bottom) one-photon absorption spectra

Results: Excited-State Spectra


Acridine
Anthracene
Anthrone
Anthrone
Azulene
Biphenyl
Carbazole
Chrysene
Coronene
Coumarin
Flourene
Flourenone
Indole
Isoquinoline
Naphthalen
Pentacene
Phenathrene
Phenazine
Phthalazine
Picene
Pyrazine
Pyrene
Pyridazine
Pyridine
Quaterphenyl
Quinoline
Quinoxaline
Stilbene
M = H2 , Metal



86 experimental values (in solution)
mean absolute error = 0.1 eV
maximum error = 0.3 eV

- Israel et al., JCP 2000: “..accurate triplet absorption spectra predictions remain a challenge..”; MRCISD-INDO/S calculations: average error of 0.4 eV
- Good agreement with experiment in our calculations for the T-T spectra applying TDDFT/B3LYP: average error of 0.1 eV

Why Simulate Ceramics Under Impact?

Idea

Ceramics have high hardness at low densities compared to metals

↓

Good candidates for armor applications (lightweight armor systems for vehicles)

Problem

They are very strong in compression but weak in tension and brittle

↓

Armor efficiency is reduced by fracture
(need for extensive ballistic studies with different materials and geometries)

Search for Solutions

Experimental impact tests

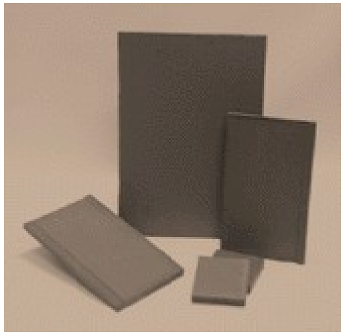
+

Computer simulations of impact
(wider choice of impact parameters)

Ceramic Applications

Ceramic Fabric

Multipurpose Tiles



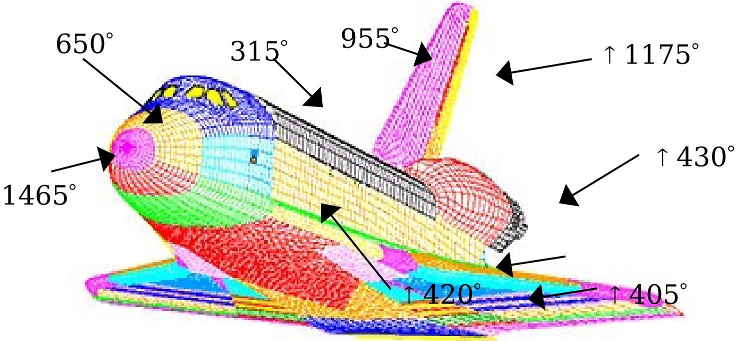
Land Vehicle Armor

Helicopter Armor

Personnel Armor

International Space Station

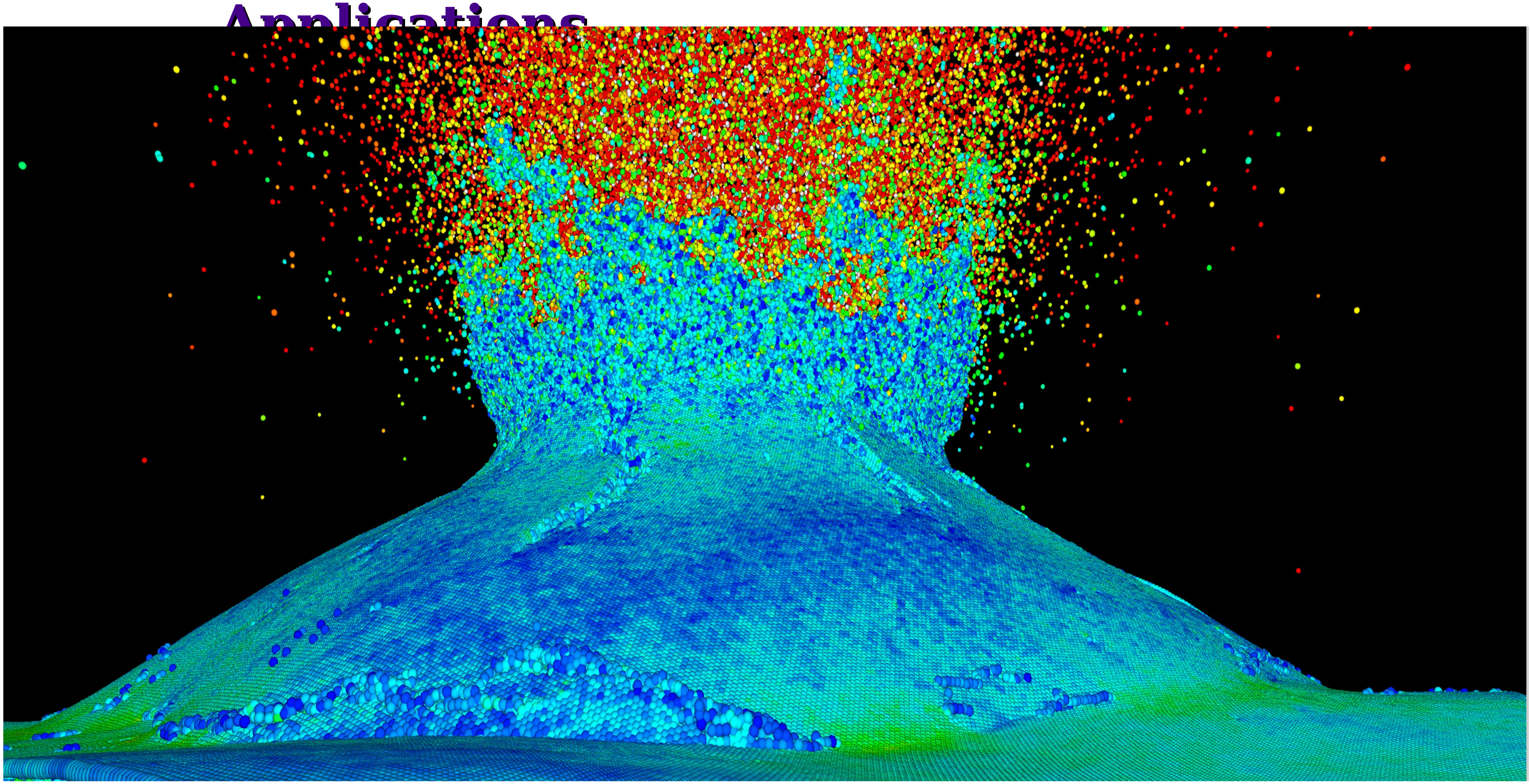
Space Shuttle


650°
315°
955°
↑ 1175°
1465°
↑ 430°
↑ 420°
↑ 405°

Temperatures in Celsius degrees
↑ are ascent temperatures

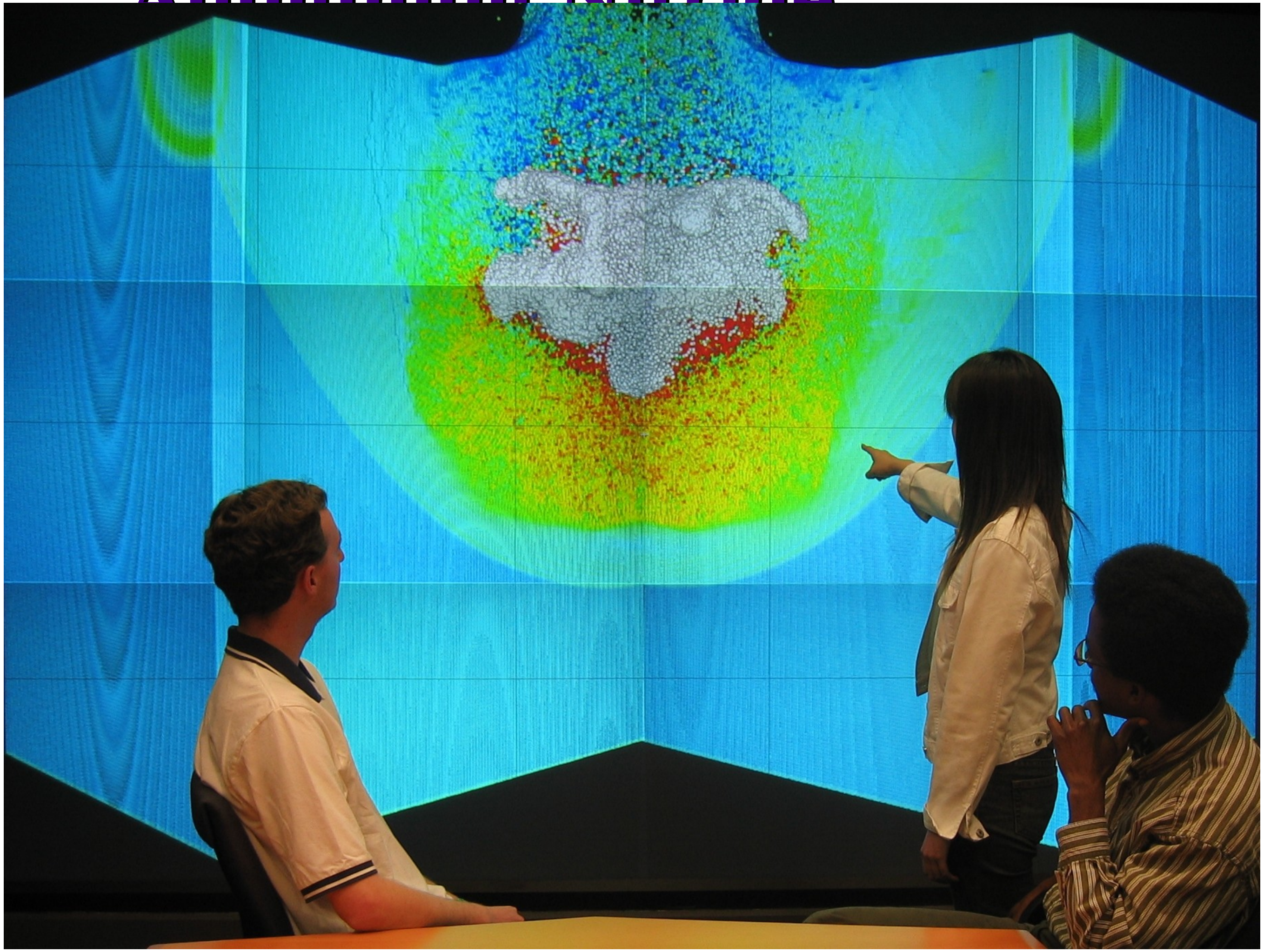
DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

209 Million Atom MD Simulation of Hypervelocity Impact in Aluminum Nitride — Lightweight Ceramic for Armor Applications

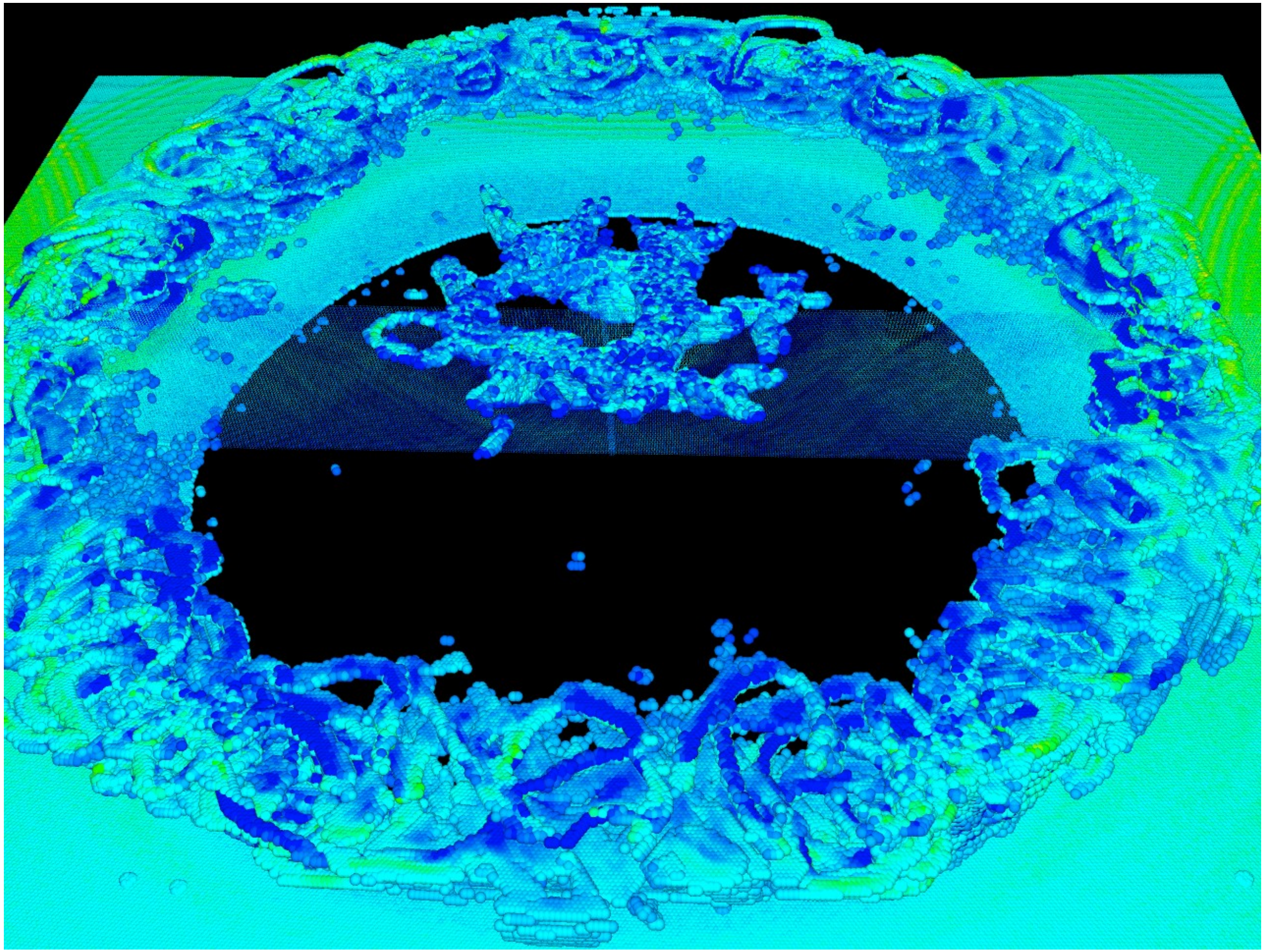


Rajiv Kalia, Aiichiro Nakano & Priya Vashishta
University of Southern California

Tiled Wall Display of 209 Million Atom MD of Shock Propagation in Aluminum Nitride



Shock-induced Damage in Aluminum Nitride



Air Force SEEK EAGLE

- USAF Aircraft-Store Certification Pr
  - Store loading procedures
  - Carriage loads*
  - Store separation*
  - Flutter
  - Ballistic accuracy
  - Stability & control*
  - Safe escape
  - Electromagnetic compatibility/interference

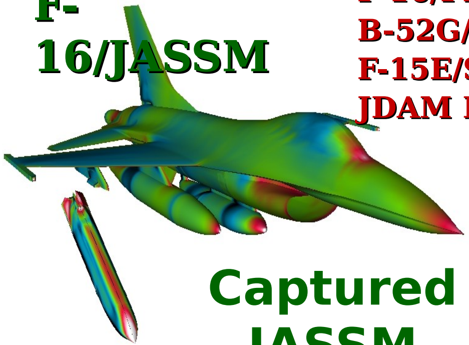
- Stores Include
  - Munitions, fuel tanks
  - Suspension equipment
  - Pods for navigating, sensing, targeting
- CFD Supports * Items Above Plus
  - Miscellaneous aerodynamic analysis, flow visualization
  - Supplements wind tunnel (not physically constrained), test analogy assumptions, reduce flight test

CFD Project Summary

FY01

- F-16/MA-31
- F-16/Mk-82 fin crack
- F-15/GBU-27

F-16/JASSM



Captured JASSM jettison!

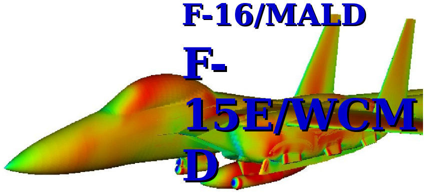
FY02

- F-111/SSB
- F-16/CBU89/JSOW
- F-16/PPB
- B-52G/JASSM
- F-15E/SLV
- JDAM FZU Sim

FY03

- F-15E/JDAM
- F-15E/SATIRS
- F-16/SNIPER
- F-15E/SNIPER
- F-15E/LITENING
- F-16/BRU/CBU89
- B-52H/X-37
- F-15E WT Support
- GBU Aero Data
- F-16/ARGUS
- F-16/MALD

F-15E/WCMD



Realistic fin deployment!

FY04

- B-52H/Mailbox
- Predator/GBU-12
- Predator unsteady flow
- SDB-FTS (GBU-39B)
- A-10/multiple stores
- B-52H/JASSM validation
- BQM-167 rocket plume
- FZU-55 on MQ-9/GBU-38
- MALD design studies
- B-1B/Mk-82/GBU-38
- F-15E S&C w/CBU-104
- F-16/600-gal tank
- B-52H/MALD
- F-16/MALD
- F-15E/GBU-28
- F-16/WCMD-ER

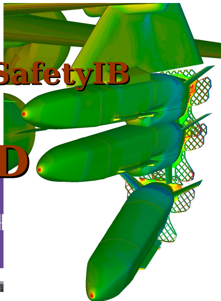
B-52H/X-37

Autopilot/flow interaction!

FY05

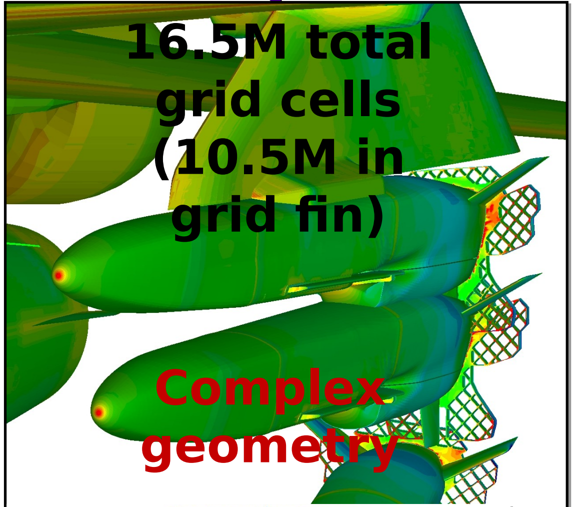
- B-1B/Mk-82/GBU-38
- B-1B/IHAAA - turbulence study
- BQM-167 rocket plume
- MALD design studies
- B-52H/MALD
- F-15E S&C w/CBU-104
- F-15E/GBU-31
- F-16 w/active control surfaces
- F-16/600-gal tank
- F-16/WCMD-ER
- F-16/ECIPS/MA-31
- F-18C/GBU-12
- C-130/Store deployment
- Condensation predictions
- B-1B/SNIPER/GBU-38
- F-15E/GBU-28
- F-15E/GBU-38
- F-15E/GBU-39
- B-52/GBU-12 SafetyIB
- B-2A/GBU-28

F-16/MALD



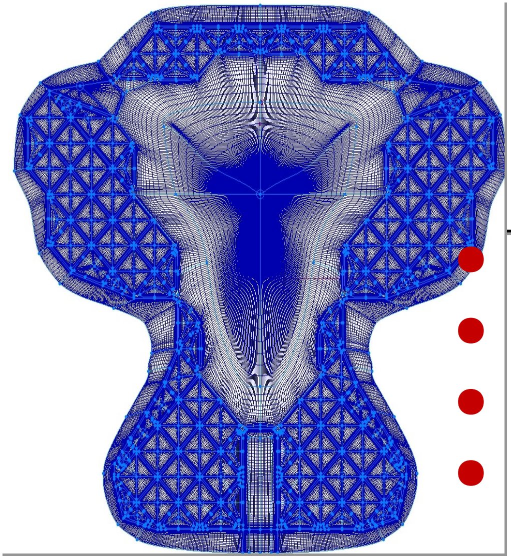
Complex grid fins!

Miniature Air-Launched Decoy (MALD)

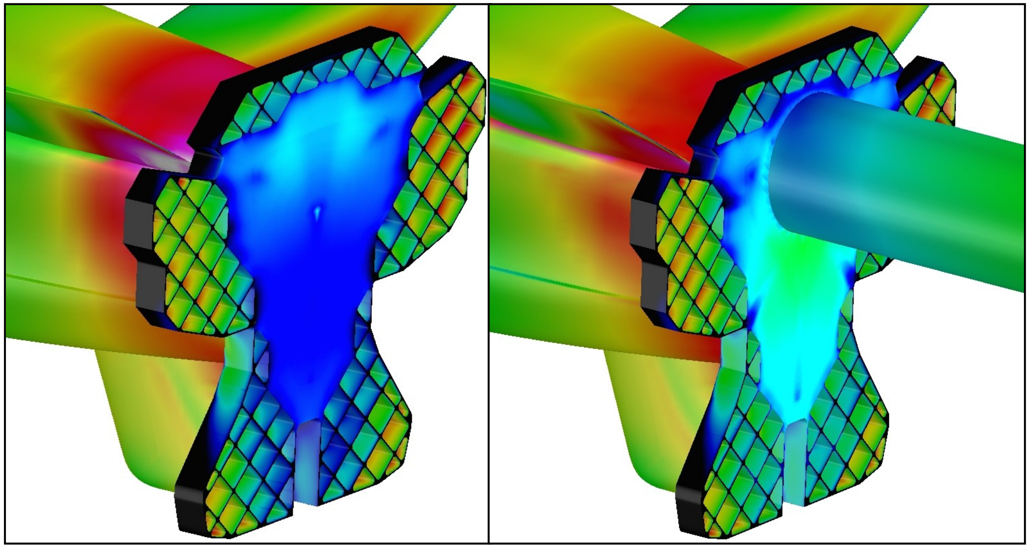


16.5M total grid cells (10.5M in grid fin)

Complex geometry



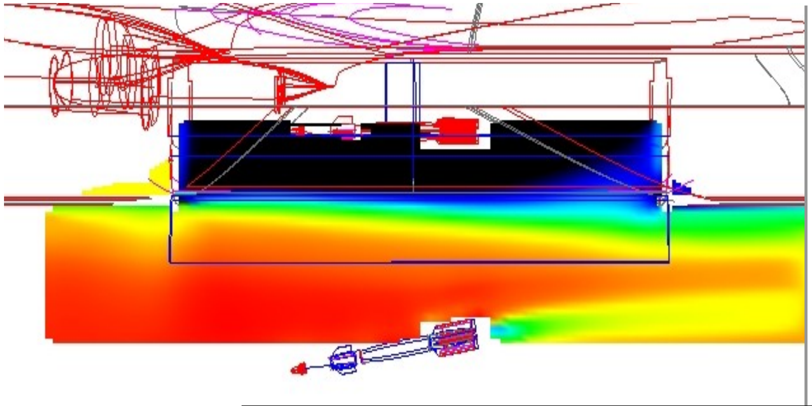
Wind Tunnel effects – less drag with sting (Mach 0.95)

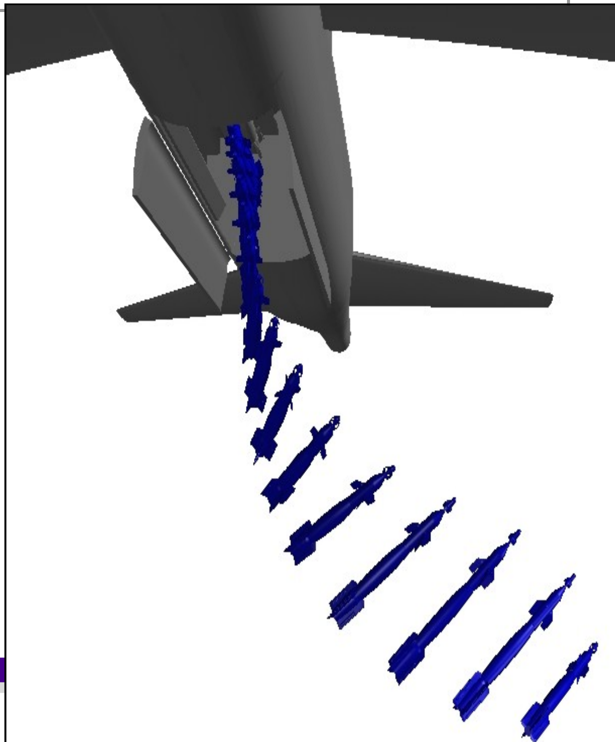


Complex flow physics

- Multiple MALD design iterations
- 32 CFD trajectories, 40 carriage, 12 freestream
- 0.6 < M < 0.95; 6k < h < 35k ft
- Good agreement w/wind tunnel & flight test (May/Jun 05)

B-52/GBU-12 Safety Investigation

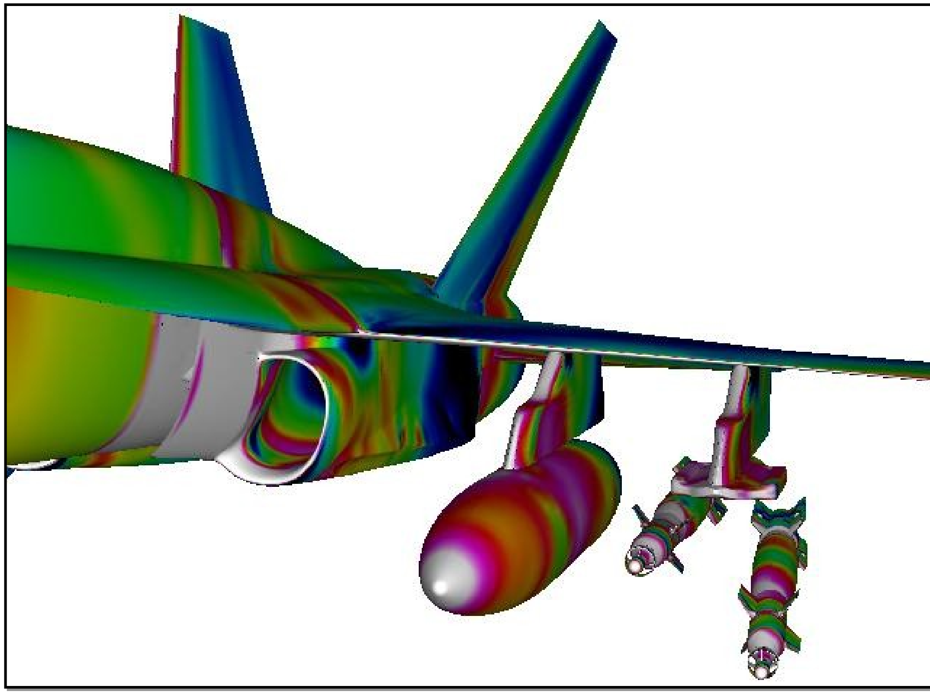




- **Accident during operational training mission**
- **Gravity-drop GBU-12 from B-52 weapon bay; sensitivity from unsteady flow, shear layer, stowed fins**
- **5 time-accurate CFD trajectories, 15 carriage/freestream in 3 weeks**
- **32M computational points**
- **Achievable only with HPC**

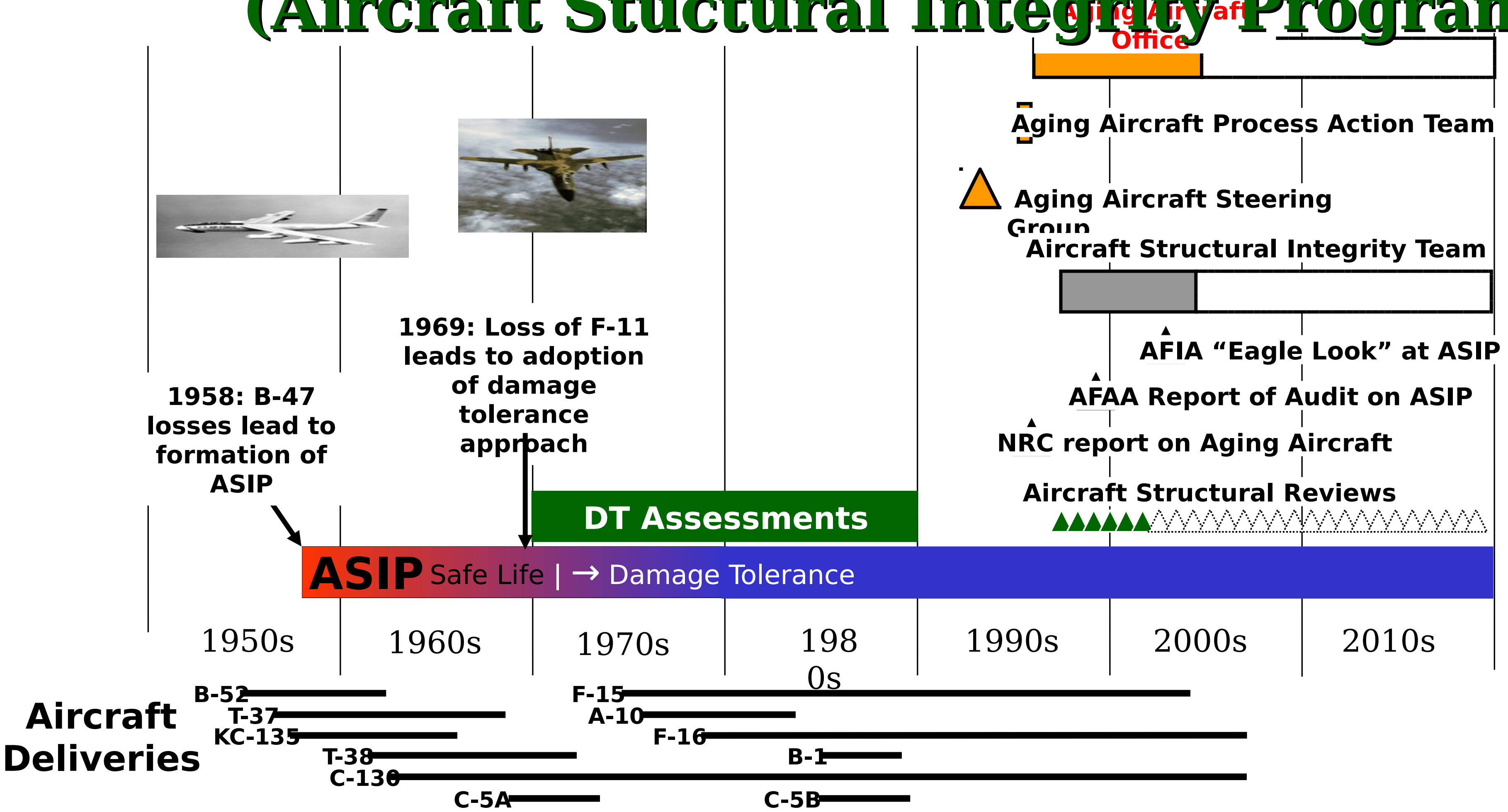
F/A-18C/GBU-12 Separation

- **Quick-reaction support for Navy flight test**
- **22M computational cells**
- **In 4 weeks - 4 CFD dynamic ripple-release GBU-12 trajectories from F/A-18C at Mach 0.88 and 1.2**
- **Saved USN $570K ($70K**



www.fas.org

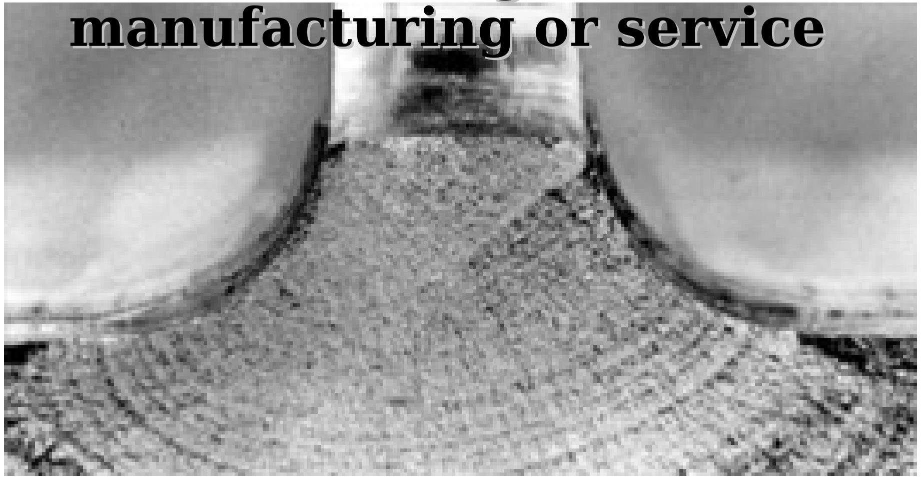
History of Structural Integrity Efforts (Aircraft Stuctural Integrity Program)

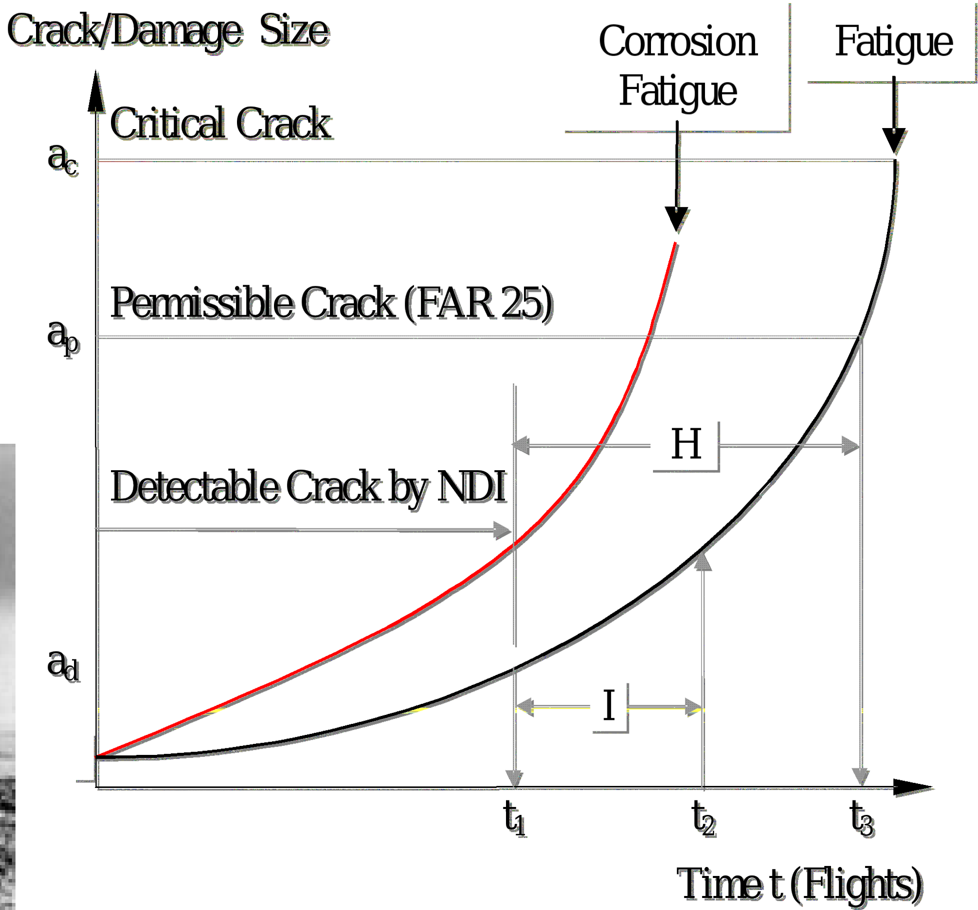


Through better designs, inspections, prevention techniques, analyses, and repairs, the AF is extending

ASIP in Practice

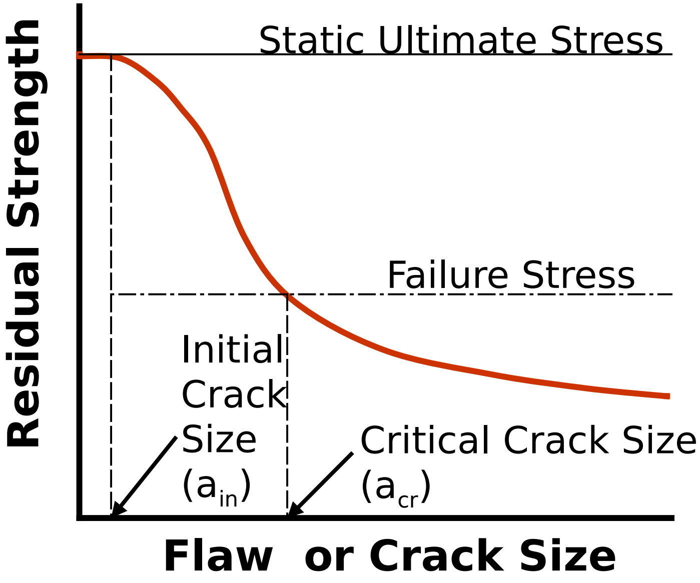
- ***Fatigue*** **– a failure caused by cyclic loading**
- **Cycles often cause the growth of cracks from inherent metallurgical features or from damage induced during manufacturing or service**



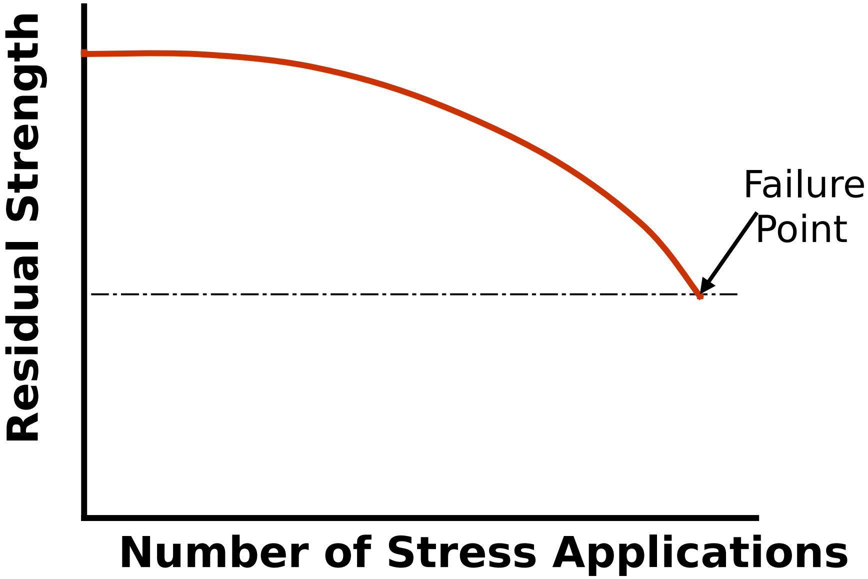


ASIP in Practice

- As a fatigue crack grows in a component, the component loses the ability to withstand stresses
- Thus, fatigue crack growth also causes a loss of ***Residual Strength***



-OR-



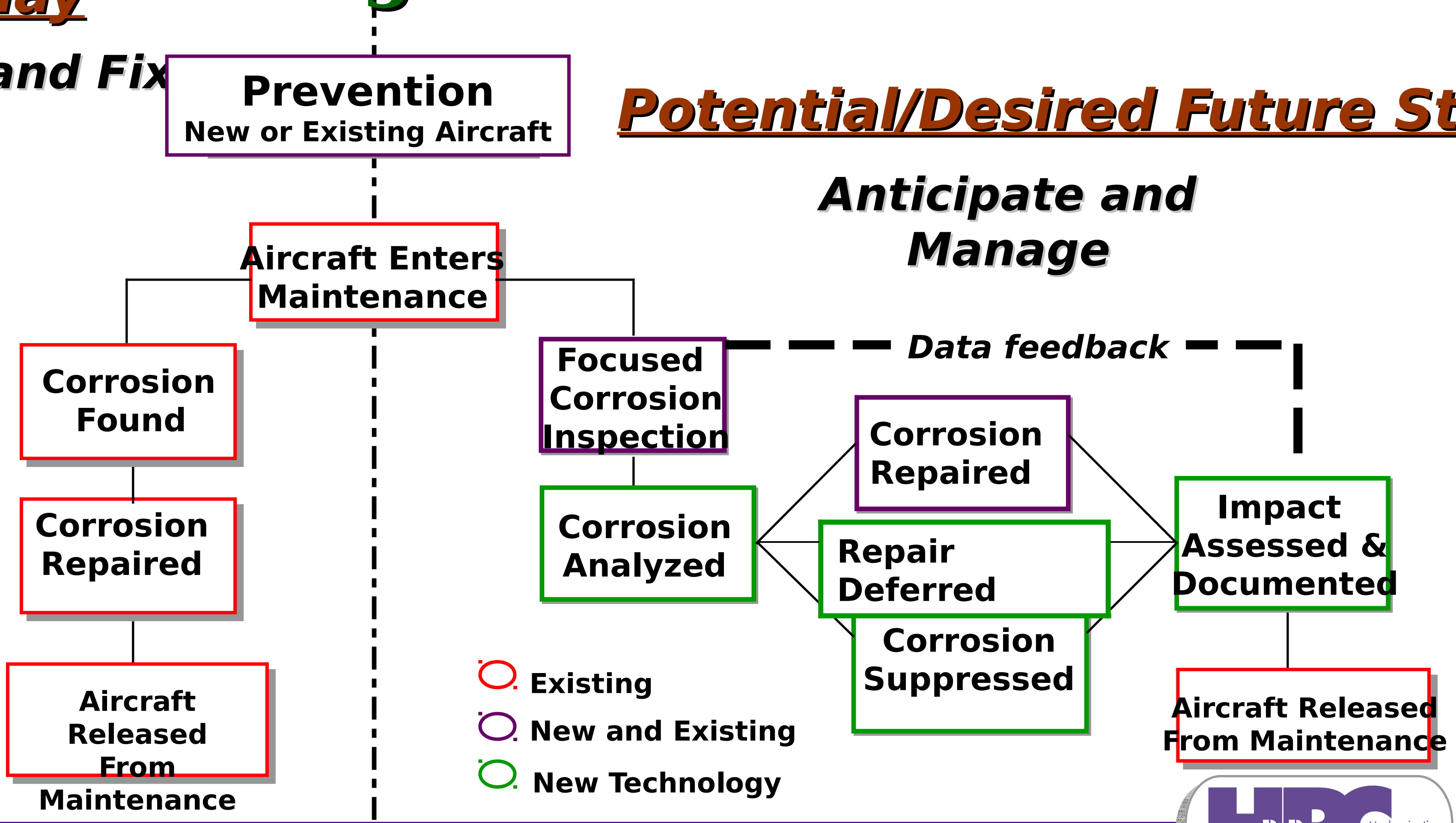
Fracture Mechanics of Fatigue Crack Growth and Failure

- **Paris Law**
  - **Crack extension per cycle** $\frac{da}{dN} = C\Delta K^m$
- **Failure Criterion** $|K_c| < |K_{Applied}|$
  - ***C, m, K_c* are material dependent parameters**
- **Stress intensity factor (K)**

$$K = \sigma \underbrace{\sqrt{\pi a}\, f\left(a/c, a/t, r/t, W, B, H, e\right)}_{\text{Component and Crack Geometry}}$$

Justification/DoD Relevance

Changing Fleet Management Paradigm



Today

Find and Fix

Prevention
New or Existing Aircraft

Potential/Desired Future Sta

Anticipate and Manage

Aircraft Enters Maintenance

Corrosion Found

Corrosion Repaired

Aircraft Released From Maintenance

Focused Corrosion Inspection

Data feedback

Corrosion Analyzed

Corrosion Repaired

Repair Deferred

Corrosion Suppressed

Impact Assessed & Documented

Aircraft Released From Maintenance

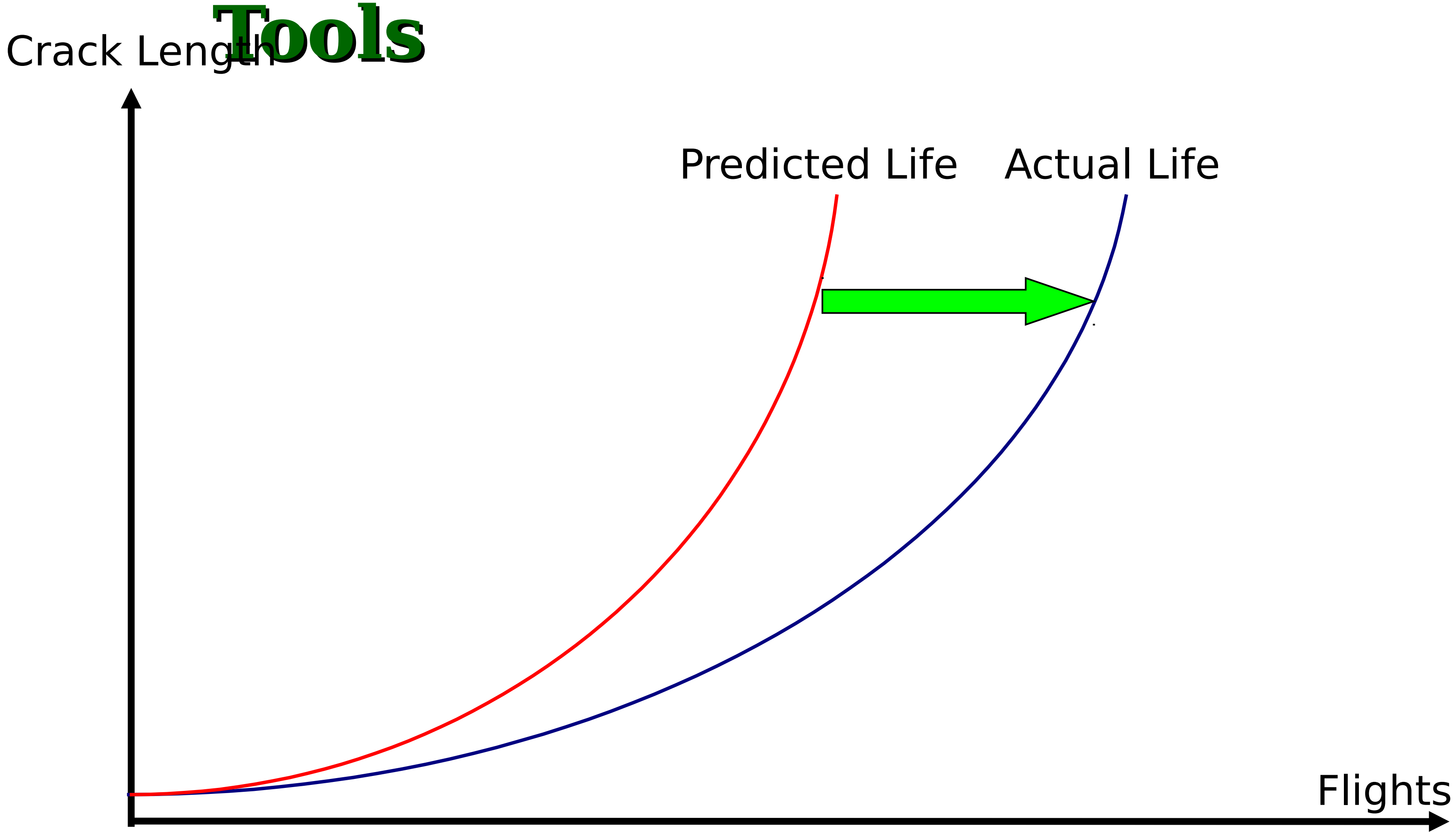
○ Existing

○ New and Existing

○ New Technology

Justification/DoD Relevance

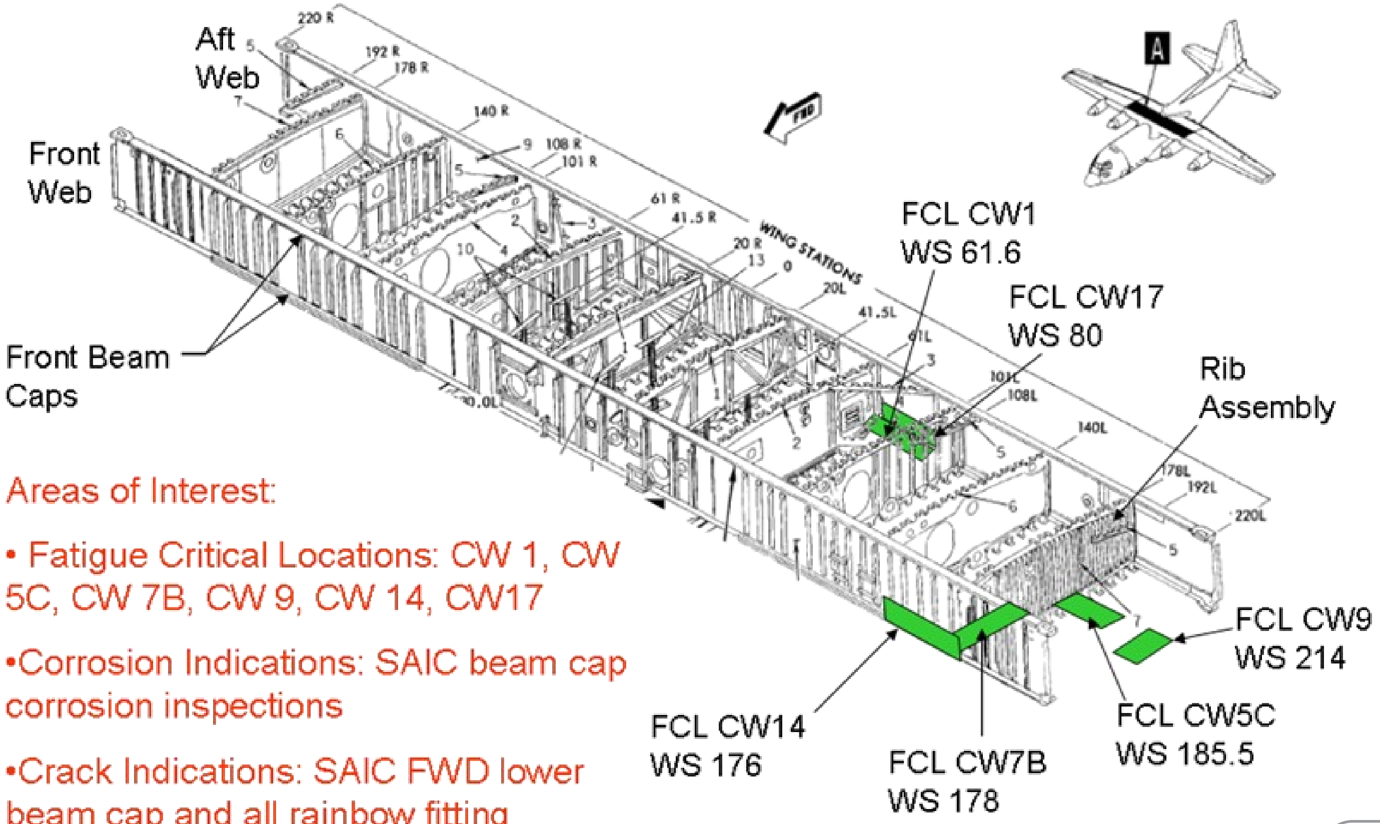
Improving Fleet Management Tools



Technical Approach

Fatigue Critical Locations in Residual Strength Analysis

Center Wing Box FCL focus from CWB Tear Down

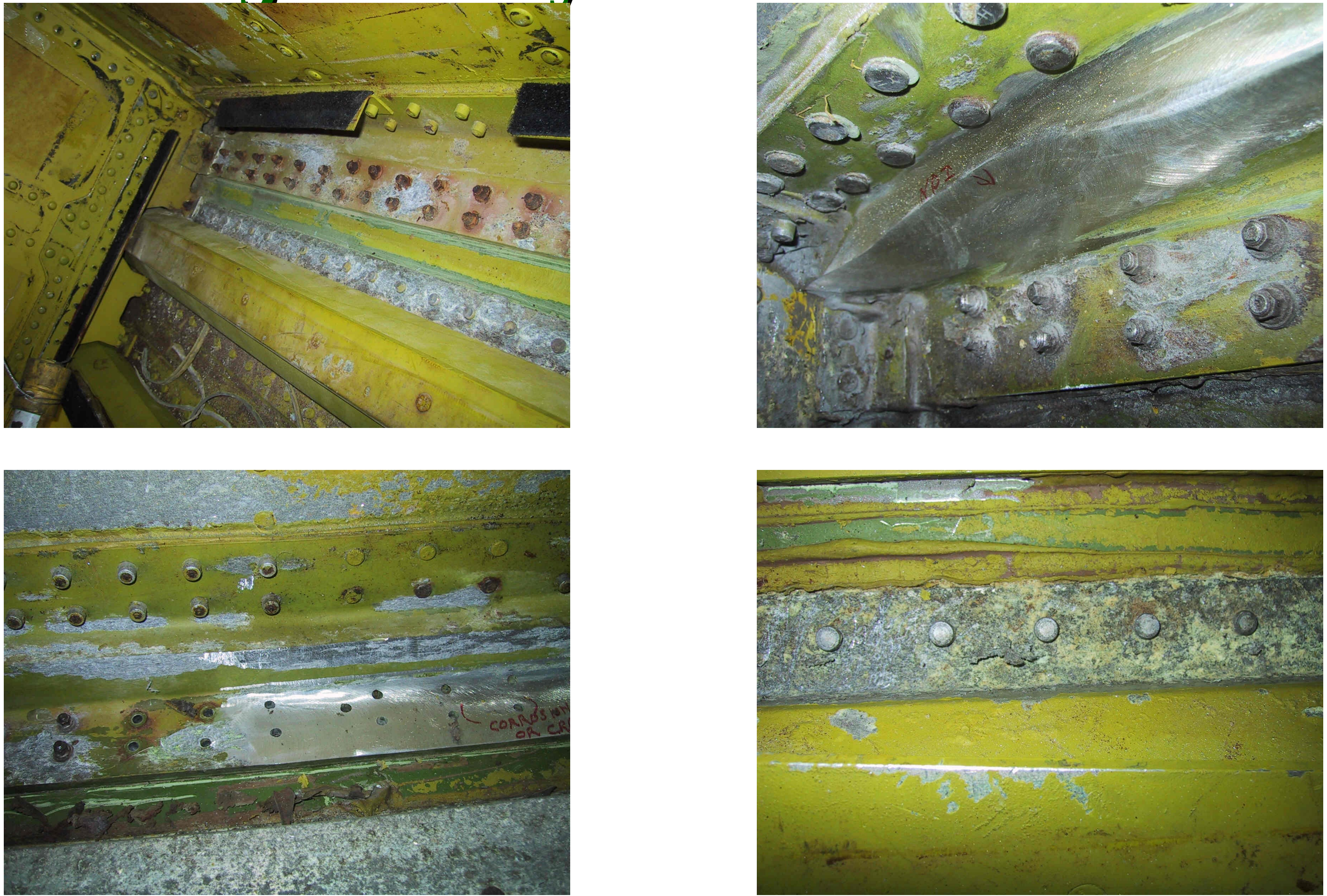

Aft Web
Front Web
Front Beam Caps
220 R
192 R
178 R
140 R
108 R
101 R
61 R
41.5 R
20 R
0
WING STATIONS
20L
41.5L
61L
101L
108L
140L
178L
192L
220L
FWD
A
FCL CW1
WS 61.6
FCL CW17
WS 80
Rib Assembly
FCL CW9
WS 214
FCL CW5C
WS 185.5
FCL CW7B
WS 178
FCL CW14
WS 176

Areas of Interest:

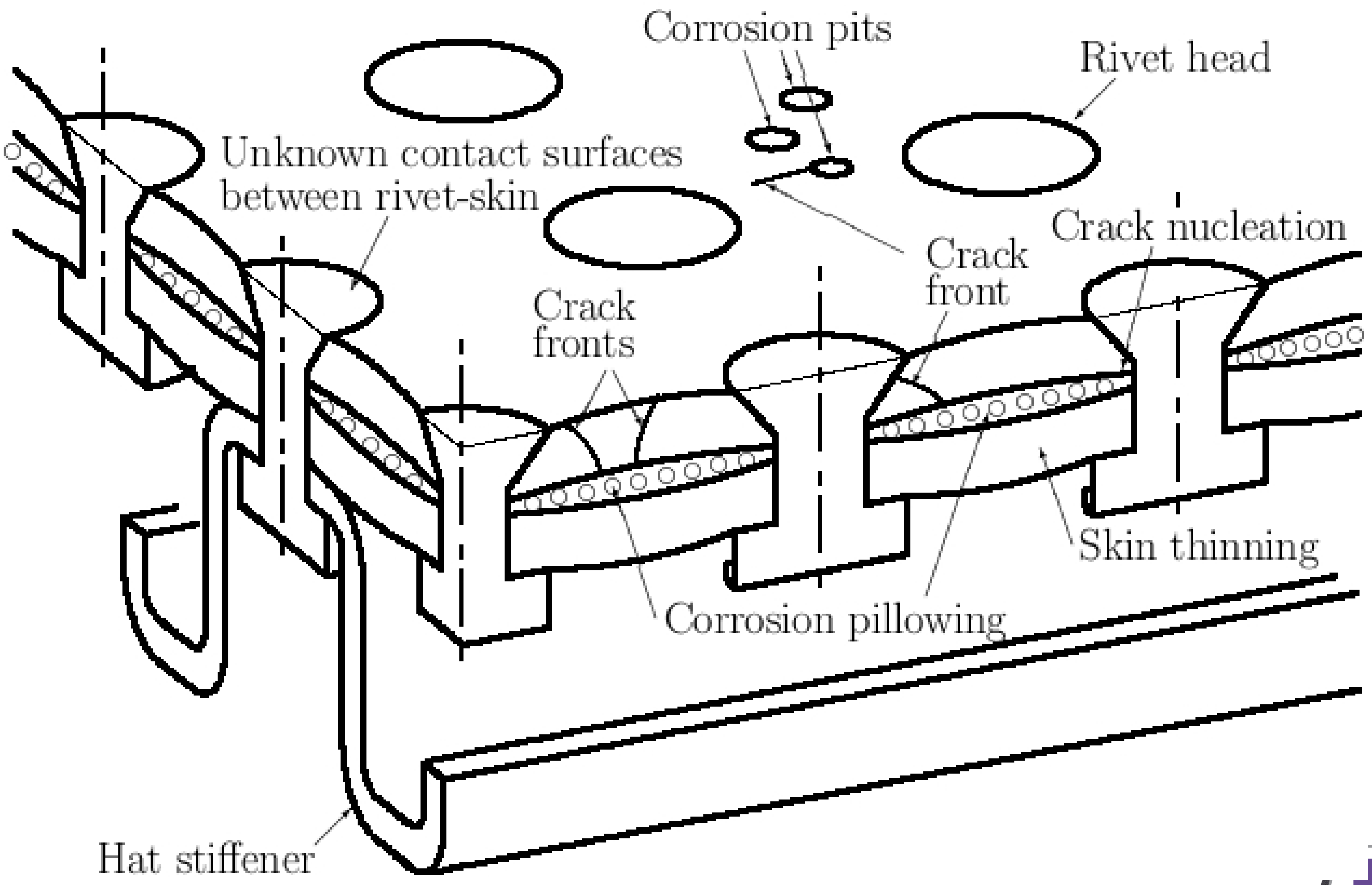
- Fatigue Critical Locations: CW 1, CW 5C, CW 7B, CW 9, CW 14, CW17
- Corrosion Indications: SAIC beam cap corrosion inspections
- Crack Indications: SAIC FWD lower beam cap and all rainbow fitting inspections for cracks

Technical Approach

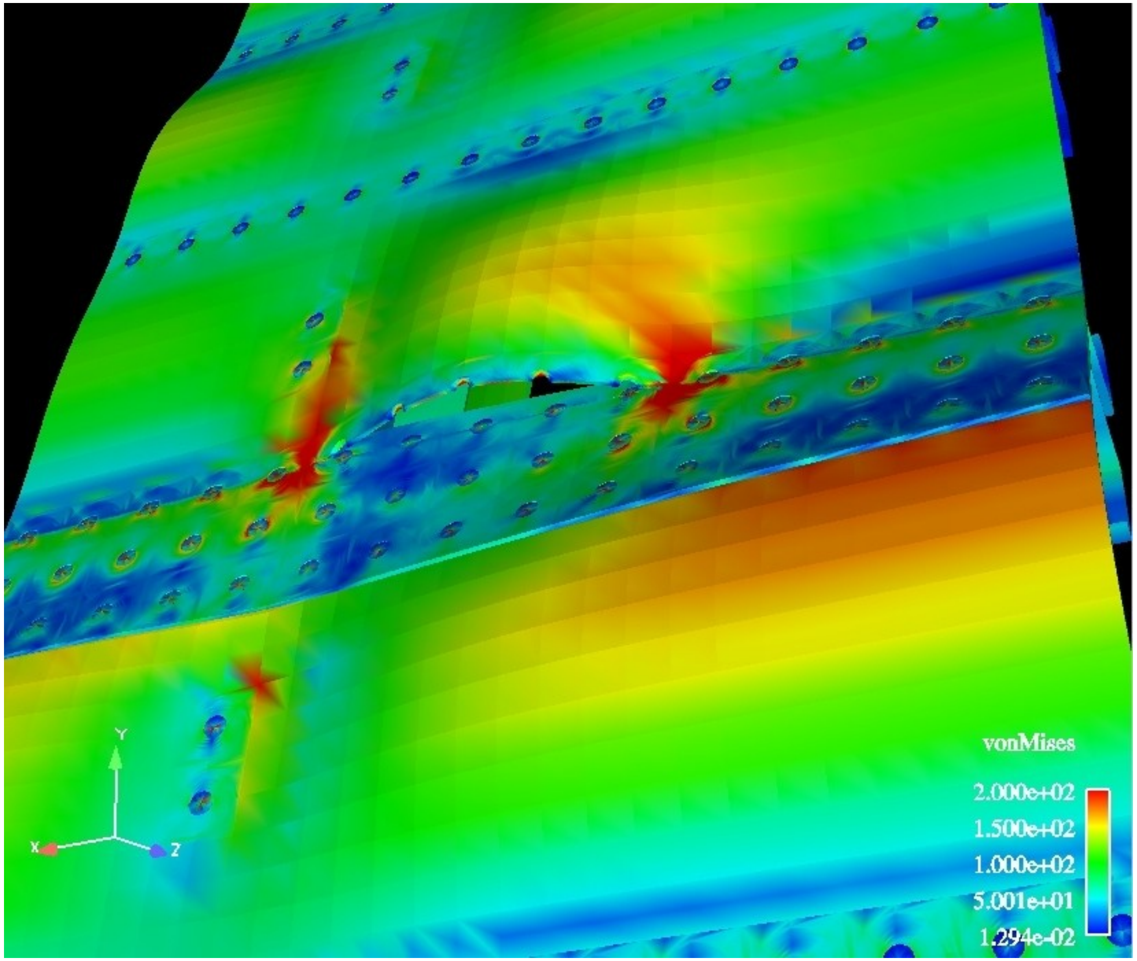
Corrosion Locations in Residual Strength Analysis


CORROSION
OR CR

Technical Approach
Modeling Corrosion


Corrosion pits
Rivet head
Unknown contact surfaces between rivet-skin
Crack nucleation
Crack front
Crack fronts
Skin thinning
Corrosion pillowing
Hat stiffener

Progress to Date
Residual Strength Analysis


vonMises
2.000e+02
1.500e+02
1.000e+02
5.001e+01
1.294e-02
Y
X
Z

Summary of Stuctural Integrity Program

- USAF uses fracture mechanics in the fleet ASIP
- USAF fleet management requires robust analysis tools move from find & fix to anticipate & manage
- 108 K-solutions and residual strength calculated using mathematical splitting scheme
  - First statistical analysis of multi-site-damage in built-up structure
- 1.9 million CPU hours used to calculate 5.6M K-solutions and large shell analyses

Summary

- World-class corporate computing capability established for DoD HPC community
- High Performance Computing capabilities being employed to provide substantial contributions to DoD mission capabilities
- Successful transition to scalable, parallel computing
- Leveraging national, academic, and federal activities